NORTH DAKOTA
DEPARTMENT of HEALTH
Water Quality

State of North Dakota Nutrient Criteria Development Plan

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HE Project No. 4965-000

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1 Introduction

1.1 Impetus for Developing Nutrient Criteria

Nutrients such as phosphorus and nitrogen are essential components used during normal biological processes within plants and animals. Nitrogen and phosphorus are naturally occurring substances, an important component of the molecular backbone of cells, and essential to sustaining life. Within surface waters, nutrients exist in a variety of forms. Nutrients may be in either particulate or dissolved phases, associated with living or senescent tissues (i.e., organic) or associated with abiotic (inorganic) material such as the soil matrix.

Elevated levels of phosphorus and nitrogen within the environment resulting from human activity can cause real (or perceived) concerns for surface water quality. These concerns become manifested when a lake, reservoir, wetland or stream fails to meet its intended societal use (i.e., beneficial use) because excess nutrients cause too much algae and/or vegetation growth (or some other consequence) resulting in an “impaired” condition. The enrichment of lakes, reservoirs, rivers and wetlands with excess nutrients is consistently one of the top causes of water resource impairment within the United States (EPA 2000).

In 1998, the U.S. Environmental Protection Agency (EPA) published the *National Strategy for the Development of Regional Nutrient Criteria* (i.e., the National Strategy). The genesis for the National Strategy stems from a foundation of technical work completed at the state, regional, and national level to assess the existing data on nutrient problems and the extent of currently available tools to assess and address nutrient enrichment (EPA 1998). This work culminated in a Clean Water Action Plan (CWAP) published in the Federal Register in March 1998, which includes the development of water quality nutrient criteria as a key component.

The National Strategy describes the approach recommended by the EPA when developing nutrient criteria and in working with States and Tribes to adopt nutrient criteria for implementation through numeric water quality standards. The intent of the National Strategy is to establish numeric water quality criteria for nutrients, implemented as standards, which curtails water quality problems stemming from excessive nutrients in the environment. The intent is to restore and protect the Nation’s water resources.

1.2 The Federal Approach to Nutrient Criteria

The EPA’s *National Strategy for the Development of Nutrient Criteria* involves a two-phased approach. During Phase I EPA developed nutrient water quality criteria (i.e., recommended concentrations) for phosphorus, nitrogen, and other parameters for use by states as a fundamental tool to begin developing state-specific nutrient criteria. The recommended EPA criteria are based upon a statistical analysis of previously collected water quality monitoring data. The recommended values for the criteria correspond to specific percentiles of the statistical distribution (see Section 3.2.1 for additional discussion) for water quality data within aggregations of Level III ecoregions.

During the second phase, each state is expected to adopt nutrient criteria for water quality to protect the beneficial uses of a state’s waters.

States and Tribes were afforded flexibility in selecting an approach for developing nutrient criteria with implementation as numeric standards. EPA provided three possible approaches from which States or Tribes could choose regarding criteria development:

1. Adopt EPA nutrient water quality criteria based on aggregated Level III ecoregions (either the established range or a single value within the range);
2. Combine the EPA recommendations for nutrient criteria with their own databases to develop their own statistically-based criteria; or
3. Use EPA methodology (or some other accepted approach) for defining criteria or, alternatively, construct a scientifically defensible method for developing nutrient water quality criteria.

The need for the State of North Dakota is to develop technically defensible nutrient criteria for surface waters, protective of the resource and consistent with federal guidance.

1.3 Scope of this Nutrient Criteria Development Plan

EPA's *National Strategy for the Development of Nutrient Criteria* recognized four major water body types:

1. Streams and rivers;
2. Lakes and reservoirs;
3. Estuaries and coastal marine waters; and
4. Wetlands.

EPA developed technical nutrient criteria guidance manuals for the first three water body types, to provide guidance and assist the States and Tribes with the development of nutrient criteria. As of August 2006, some publications (Wetland Modules) are available for monitoring and assessing wetlands, but the complete guidance manual remains unavailable.

This plan describes the anticipated conceptual approach for developing nutrient water quality criteria by the State of North Dakota. The plan specifically focuses on lotic systems (i.e., small to large wadeable and non-wadeable streams and rivers) and lentic systems (i.e., lakes and reservoirs). The plan currently excludes wetlands, although the issues discussed and recommended methods are potentially applicable to wetland systems.

For lotic and lentic systems, the plan:

1. Defines a recommended approach for developing nutrient criteria;
2. Identifies the data needed to develop the nutrient criteria; and
3. Where possible, identifies key issues, milestones and decisions.

While the scope of the plan is intended to provide clear and meaningful guidance for the development of nutrient criteria within North Dakota, resolving certain ambiguities or unknowns associated with the amount and quality of data necessary to develop the criteria is beyond the scope of this plan. This plan represents a road map for use by the

State of North Dakota to navigate through the complex issues related to developing nutrient criteria appropriate for (and protective of) its surface water resources. A complete analysis of the data needed to develop the criteria, the analysis and development of the criteria and criteria implementation as water quality standards is expected to occur subsequent to the completion of this report. As recognized by EPA, the report does not represent a binding commitment and modification of the plan will likely be needed as new information becomes available or unanticipated issues arise (Grubbs 2001). This plan is consistent with the content for a nutrient criteria plan as required by the EPA.

1.4 Nutrient Criteria Development Philosophy

The development of nutrient criteria by the State of North Dakota is driven by three fundamental considerations. These considerations are that the criteria developed should be:

1. Protective of the State's water resources and their designated beneficial uses;
2. Tailored to the unique physiographic characteristics and water resources of this northern plain (prairie) state;
3. Technically and scientifically defensible; and
4. Based upon conceptual ecosystem models that reflect cause (stressor) – effect (response) relationships founded on excess nutrient concentrations and that reflect the reasons for resource impairment (e.g., excessive algae in a lake) and the loss of beneficial uses.

These considerations guide the recommended approach presented by the plan.

2 Data Available to Develop Nutrient Criteria

2.1 Overview

A broad array of literature and water quality data were reviewed and assessed while preparing the nutrient criteria development plan for North Dakota. The literature reviewed included reports and information specific to North Dakota (see Section 2.5), other states which have or are developing nutrient criteria development plans, and EPA national guidance material. North Dakota surface water monitoring data, obtained from the NDDH, the United States Geological Survey (USGS) and from EPA, were reviewed and summarized. The objective for the literature and data review was to understand potential options (including benefits and limitations) for North Dakota in establishing an approach for developing nutrient criteria. A thorough statistical analysis of the data to develop the criteria is expected during the implementation of this plan. The analysis presented in this plan is primarily intended to understand the limitations of the available data and the need for collecting additional data when developing criteria.

2.2 Section 305(b) Assessment Data

2.2.1 Overview

Section 305(b) of the Clean Water Act requires states to develop a comprehensive biennial report on the quality of state waters. North Dakota is characterized by four Level III ecoregions and five major basins (**Map 1**), which ultimately drain to Canada and South Dakota. A narrative summary of Level III ecoregions is found in **Appendix A** and a summary description of major basins is found in **Appendix B**. The basins and associated surface waters are shown in **Maps 1 and 2**. To help manage surface waters the State recognizes five hydrologic basins as:

1. Red River (including Devils Lake and the Upper and Lower Red River Subbasins);
2. Souris River;
3. Upper Missouri River (Lake Sakakawea);
4. Lower Missouri River (Lake Oahe); and the
5. James River.

For the 305(b) assessment effort, the NDDH evaluates data collected on most of the publicly managed lakes and reservoirs. However, the many lotic (flowing) systems means that only a relatively small portion of streams and rivers can be feasibly assessed through the collection and analysis of water quality samples (i.e., monitoring). While an estimated 2.5 million acres of wetlands are present in North Dakota, these lentic systems are currently not assessed by the state, although a monitoring and assessment program is under development.

2.2.2 Lakes and Reservoirs

The NDDH currently recognizes 224 lakes and reservoirs for water quality assessment purposes. Of this total, there are 134 reservoirs and 90 natural lakes (**Table 1**). Two reservoirs (Lake Sakakawea and Lake Oahe) located on the mainstem of the Missouri River comprise 67 percent of the state's combined lake and reservoir surface area. Seventy-three (73) percent of the total area comprised by the 90 natural lakes in North Dakota is attributed to Devils Lake. Natural lakes, with the exception of Devils Lake, tend to be under represented in the State relative to the total surface area of lakes and reservoirs.

2.2.3 Streams and Rivers

The NDDH evaluated over 10,000 miles of streams and rivers for water quality assessment purposes. There are 54,427 miles of streams and rivers in the state, of which only 10 percent are considered perennial (**Table 2**). North Dakota shares perennial systems with South Dakota and Minnesota, including the Bois de Sioux River and the Red River of the North, respectively. Together these border rivers total 427 miles in shared length, which is almost 8 percent of North Dakota's total perennial system length. The perennial and ephemeral (intermittent) streams and rivers in North Dakota are distributed somewhat unevenly across the state with more ephemeral streams in the west.

2.3 Section 303(d) Impairments

Section 303(d) of the Clean Water Act requires states to develop a list of waters which, through the assessment processes, are identified as not meeting beneficial uses established by the State. Impaired waters identified in 2006 are shown in **Map 3** and summarized in **Tables 3 and 4**. Four beneficial uses (aquatic life, recreation, drinking water, and fish consumption) were assessed for purposes of Section 305(b) reporting and Section 303(d) lists. Water bodies can be water quality limited and therefore placed on the Section 303(d) list due to a variety of pollutants from sources including point sources, nonpoint sources, or both.

The NDDH uses a suite of indicators to assess beneficial use attainment and impairment, and to determine causes and sources of stressors affecting water quality. The NDDH uses a tiered approach that combines core indicators selected for each beneficial use and water resource type combination, plus supplemental indicators selected according to site-specific or project-specific considerations. Core and supplemental indicators[1] for each water resource type include physical, chemical, habitat, biological, and landscape variables and metrics. While there are a number of lakes and reservoirs listed on the Section 303(d) list for eutrophication / nutrient enrichment, there are no river and stream segments currently listed on the Section 303(d) list because of excess nutrients. Some water bodies may also be listed because of the manifestation of excess nutrients like low dissolved oxygen concentrations.

[1] The terms core indicator and supplemental indicator are used by the NDDH for assessing impairment of a water body. These indicators may also be considered "response variables" or "affect variables" as used in this plan, which are the manifestation of excess nutrients.

2.4 Available Water Quality Data

2.4.1 NDDH Water Quality Monitoring

The NDDH has a ten year strategy drafted for monitoring the water quality of surface waters. This strategy builds on the foundation laid by previous monitoring efforts within the state. The NDDH establishes four categories of monitoring efforts:

1. Condition monitoring;
2. Problem investigation monitoring;
3. Effectiveness monitoring; and
4. Special studies monitoring.

These categories help distinguish between the various purposes of the monitoring programs and projects necessary to meet the goals and objectives of the NDDH ten year strategy.

In 1991, the NDDH initiated the Lake Water Quality Assessment (LWQA) Project. Since that time, the NDDH has completed sampling and analysis for 111 lakes and reservoirs in the state. Lentic sampling sites are shown in **Map 4** and summarized for select parameters applicable to developing nutrient criteria in **Table 5**. The results from the LWQA Project have been prepared in a functional atlas-type format. Each lake report discusses the general description of the water body, general water quality characteristics, plant and phytoplankton diversity, trophic status, and watershed condition. Beginning in 1997, the LWQA Project activities were integrated into the NDDH's rotating basin monitoring strategy. In addition to its inclusion in the annual LWQA Project, Devils Lake and Lake Sakakawea have received special attention.

The NDDH first conducted state-wide biological monitoring of its streams and rivers from 1993 through 2000 using a rotating basin approach with intensive targeted chemical sampling sites. Lotic water quality sampling sites are shown in **Map 5** and summarized by select parameters in **Table 6**. The rotating basin monitoring program was discontinued in 2001 while the NDDH focused its resources in support of sampling for EPA's Environmental Monitoring and Assessment Program (EMAP) Western Pilot Project (see Section 2.4.3). Some biological monitoring data (i.e., macroivertebrate and fish abundance) has also been collected by the NDDH (**Map 6**).

Table 6 shows limited available chlorophyll-a data, with the exception of Level III ecoregion 48, for rivers and stream. Considerable total phosphorus and total nitrogen data are available across all Level III ecoregions for rivers and stream. Considerable total phosphorus, total nitrogen and chlorophyll-a data are available across all Level III ecoregions for lakes and reservoirs.

2.4.2 National Water Information System

The USGS collects and analyzes chemical, physical, and biological properties of water, sediment and tissue samples from across the Nation. These data are accessible through the USGS National Water Information System (NWIS). There are a total of 1,302 sites within lentic or lotic systems which have been sampled by the USGS in North Dakota. Existing sampling sites on lentic and lotic systems are shown in **Maps 4 and 5,** respectively. Select parameters of interest are summarized in **Tables 7 and 8**. Within the last ten years, roughly 46 lentic sites and 105 lotic sites have been sampled for nutrients. However, one water body may be associated with several sample sites, such as Lake Sakakawea or Devils Lake. Although the USGS dataset shows considerable data across all Level III ecoregions for total phosphorus and total nitrogen, limited chlorophyll-a data are available for lakes and reservoirs or streams and rivers. Chlorophyll-a data are available for Devils Lake, the Chain of Lakes in the Devils Lake basin, Lake Darling, select locations on the Souris River and select locations within the Missouri River system.

2.4.3 EMAP Western Pilot Project

EPA's Environmental Monitoring and Assessment Program (EMAP) Western Pilot Project is intended to help establish reference conditions for wadeable streams. The primary goal of the EMAP Western Pilot Project is to generate state and regional scale assessments of the biological condition of wadable perennial rivers and streams in the western United States and to identify stressors associated with the degradation of these resources. In 1999, EMAP embarked on a multi-year effort to demonstrate the application of core monitoring and assessment tools across a large geographical area of the western United States. The EMAP-West project includes the twelve conterminous states in EPA Regions 8, 9, and 10. The surface water component of EMAP-West has developed a set of indicators of ecological condition and environmental stressors. These include:

1. Biological assemblages (fish, macroinvertebrates, and algae);
2. Ambient water chemistry (nutrients, acid/base status, etc.);
3. Fish tissue contaminants (mercury, metals, PCB congeners, persistent organics);
4. Physical habitat (sedimentation, in-stream / riparian habitat structure, etc.); and
5. Watershed characteristics.

Within North Dakota between 2001 and 2004, a total of 113 samples were collected characterizing wadeable streams. Sampling sites are shown in **Map 5** and summarized by select parameter in **Tables 9 through 11**. Sites were chosen by EMAP staff in consultation with State staff, based on a random (i.e., probabilistic) site-selection process. However in some instances, duplicate sampling efforts were performed on one date at a single station (i.e. reach-wide versus targeted riffle sampling).

Table 9 shows that during the EMAP Western Pilot Project no chlorophyll-a or periphyton data were collected within lotic systems. Water quality data were primarily collected for lotic systems within Level III ecoregions 43 and 48, and excluded regions 42 and 46. Reference sites were primarily located in ecoregions 43 and 48 (see **Table 11**). These data are expected to be useful in obtaining a general sense of total phosphorus and total nitrogen concentrations at reference sites within two ecoregions, but of limited value in establishing the cause – effect relationship or establishing ecological endpoints except within ecoregions 43 and 48. A suite of biological indicators were collected along with the chemical water quality data.

2.4.4 Sheyenne River Pilot Study

The NDDH commissioned a pilot study, funded by the EPA (Zheng et al., 2004) to evaluate the development of potential nutrient criteria for wadeable streams within the Northern Glaciated Plains ecoregion (46). Ecoregion 46 includes the Sheyenne River and its' tributaries. The pilot study evaluated a suite of stream metrics as well as land use factors. Fourteen sites were selected as targeted reference sites within the area contributing runoff to the Sheyenne River. Two additional sites were selected outside of the Sheyenne River watershed as reference sites. Sampling occurred over a two-year (2001-2002) period. Recommended nutrient criteria were developed during this pilot study for total nitrogen, nitrate-nitrite nitrogen, total phosphorus, and soluble phosphorus. The nitrogen criterion developed during the pilot was similar to those recommended by EPA using a statistical approach for the aggregate ecoregions. The pilot study recommended a criterion for total phosphorus considerable greater than that recommended by EPA. The pilot study recommended an approach to developing nutrient criteria which consisted of combining information from reference sites with effects-based relationships of macroinvertebrate response.

Several lessons were learned from the completion of the pilot study. Identifying conditions considered as "reference" proved challenging, because of the considerable anthropogenic disturbance within the watershed. Nitrogen rather than phosphorus may be the nutrient limiting primary productivity. Measuring periphyton biomass proved challenging, and generally periphyton and diatom assemblages did not show a pattern of change in response to nutrient concentrations or other environmental variables. Duplicate periphyton samples tended to show low similarity (i.e., poor precision), suggesting challenges with the sampling method. Macroinvertebrate assemblages were associated with environmental variables, primarily the number of EPT taxa.

2.4.5 Statistical Analysis of Existing Data

The EPA Region 8 contracted with Dr. Pete Richards from Heidelberg College to apply EPA's recommended statistical approach to the state's water resources. The effort resulted in the determination of potential draft nutrient criteria for Level III ecoregions within North Dakota, based on currently available data **(Table 12).** Based upon the statistical analysis, agreement between the potential criteria as derived by EPA and Dr. Richards varies. The primary limitation with the analysis is the lack of a cause-effect relationship.

2.5 Literature Review

2.5.1 Overview

A diverse assemblage of literature relating to nutrient criteria development was compiled and reviewed (**Table 13**). The literature reflected federal technical guidance documents, fact sheets, and other information, as well as nutrient criteria plans from many states. Nutrient criteria plans from 14 states were screened to identify those with relevance to North Dakota.

2.5.2 Documents Relevant to North Dakota

There is potential value to North Dakota from building upon existing nutrient criteria plans. Most notably, it allows the state to understand the rationale for developing criteria and utilize a proven, successful strategy. It allows the state to select the most salient pieces of each plan to develop its own tailored approach to developing nutrient criteria. Nutrient criteria plans from 14 states were screened to identify those which were deemed as having particular relevance to North Dakota.

The documents from six states seemed especially applicable to North Dakota. Key components of the six nutrient criteria plans are summarized in **Tables 14 and 15**. Several factors were generally considered when assessing the relevance of a state's nutrient criteria plan to North Dakota, including similar water resources, geographic proximity, scientific rigor of the plan, and ability (based on staff and financial reseources) to implement the plan. The following state plans were identified as relevant to North Dakota:

1. California;
2. Colorado;
3. Florida;
4. Minnesota;
5. Montana; and
6. Utah.

The content and detail contained in each plan varies considerably. The key components of some plans were difficult to clearly and concisely summarize in categorical form. In large part, this is due to the open-ended nature of the narrative found within several plans. While this affords a certain level of flexibility, it also reduces the utility of the nutrient criteria development plan itself. However, given that caveat, the approaches proposed for North Dakota generally align with those of other relevant states.

Based upon the literature review, several items seemed relevant to developing nutrient criteria within North Dakota:

1. Omernick Level III or IV ecoregions represent a good spatial scale for developing nutrient criteria for streams and rivers;
2. Nutrient criteria should be seasonal, reflective of the temporal response of the resource;
3. The application of EPA's recommended approach of the 25^{th} percentile for the monitoring data "population" can result in unduly restrictive criteria;
4. Using a 75^{th} percentile concentration for sites identified as "reference" is preferred over the 25^{th} percentile for the monitoring data "population" recommended by EPA;

5. Nutrient concentrations established using regional stressor – response[2] field studies tend to fall within a narrow band around the 85th percentile value using reference site data;
6. The selection of nutrient criteria based on a statistical approach (including EPA's recommended approach) is best supported by ground-truthed field data used to develop a site specific stressor – response relationship;
7. The nutrient criteria should ideally include some expression of uncertainty (e.g., confidence interval) which reflects the inherent variability of natural systems, both in terms of the stressor – response relationship and the beneficial use impairment;
8. Common sense should be applied when using a statistical approach (i.e., consideration given to censoring techniques, sample size, correlation among causal variables, the type of statistical distribution);
9. Many states prefer the use of a reference approach, either to establish the form of the stressor – response relationship or for applying a statistical approach. However, identifying "reference" for large river systems can be challenging;
10. Identifying the limiting causative factor(s) for some systems can be a challenge;
11. Spatially varying nutrient criteria on large lakes and reservoirs may be necessary to be protective and represent the naturally occurring longitudinal change in water quality;
12. Criteria are intended to be regionally protective. Site-specific data developed through the completion of a total maximum daily load study may still be needed to protect a specific water body; and
13. Few states have actually implemented their criteria – so additional lessons can be learned.

The intent is to incorporate the relevant lessons learned from the literature review into the North Dakota nutrient criteria development process.

[2] The terms "stressor – response" and "cause – effect" are used interchangeably, to mean the change in a water body in response to excess nutrients.

3 Proposed Nutrient Criteria Development Strategy

3.1 Nutrient Criteria Development Framework and Concepts

This section presents a proposed strategy for developing nutrient criteria for the State of North Dakota. The ability to implement this strategy will be largely based upon the availability of good quality surface water quality monitoring data to identify and verify reference sites and statistically defensible stressor – response relationships. Therefore, the approach should be considered "preliminary" with revisions necessary as more detailed information becomes available. The intent is to provide sufficient detail within this plan to generally identify the anticipated criteria development approaches for lotic (i.e., rivers and streams) and lentic (i.e., lakes and reservoirs) systems sufficient to secure additional funding. This funding is needed to conduct the studies to develop the data to establish nutrient criteria.

3.1.1 Spatial (Geographic) Scale for Criteria Development

Nutrient criteria may be developed on a site specific basis (i.e., individually for each water body) or across some larger geographic area (e.g., region or state). The advantages of developing the nutrient criteria across some larger geographic area are that 1) a lesser level of effort may be required to develop the criteria, because criteria are not developed individually for each water body using site specific data, and 2) there is greater consistency of the criteria when it is applied across a larger area. The disadvantage is that the criteria may be over or under protective of the resource's beneficial uses, because they are generalized.

Two alternative spatial scales, ecoregions and major surface water hydrologic basin, have been considered for criteria development. *It is the recommendation of this plan to use a nested approach of Level III ecoregions (**Map 1**) further subdivided by major surface water hydrologic basins (**Map 2**) for nutrient criteria development.* The intent is a geographic scale which separates large river systems like the Missouri River, which are influenced considerably by conditions beyond the State's border. Using major surface water basins as the primary spatial scale rather than ecoregions may have an advantage. This will be evaluated further once statistical analysis of the data begins. Large reservoirs are expected to behave differently than most water features within their ecoregion. The water quality of large rivers and the mainstem reservoirs (Lake Sakakawea and Lake Oahe) is influenced considerably by the large amount of drainage area beyond the North Dakota border. Additionally, there are numerous perennial lotic systems which flow through more than one ecoregion.

Using ecoregions alone, rather than a nested approach should be considered if the nested approach proves difficult. Previous statistical analysis of North Dakota stream and lake data by Dr. Richards did not conclusively indicate significant differences in potential nutrient criteria among all ecoregions. Statistically significant differences between some ecoregions were determined for select parameters (e.g., total phosphorus and total nitrogen). In part this analysis was hindered by an inadequate spatial distribution in data collection. A nested approach may prove cumbersome and difficult to apply, simply due to the number of criteria that would need to be developed and the amount of data required. The nested approach also implies that significant differences would exist in water quality among ecoregions within a hydrologic basin. An advantage of the nested approach is that criteria and data can always be aggregated using a larger spatial scale. Some initial work will be necessary to select the "best" spatial scale.

3.1.2 Temporal Scale for Criteria Development

Nutrient criteria should ideally be developed in a manner, which reflects the timing (when during the year) and duration (how long) of the beneficial use impairment. The timing and duration of the beneficial use impairment may differ from the timing and duration of the factors leading to the impairment. For example, the timing and duration of an algal bloom in a lake or reservoir during the growing season may be caused by an episodic pulse in nutrient load in the spring. Nutrient criteria need to include a temporal component (i.e., the time of year they apply and any duration or recurrence or averaging period) associated with the criteria.

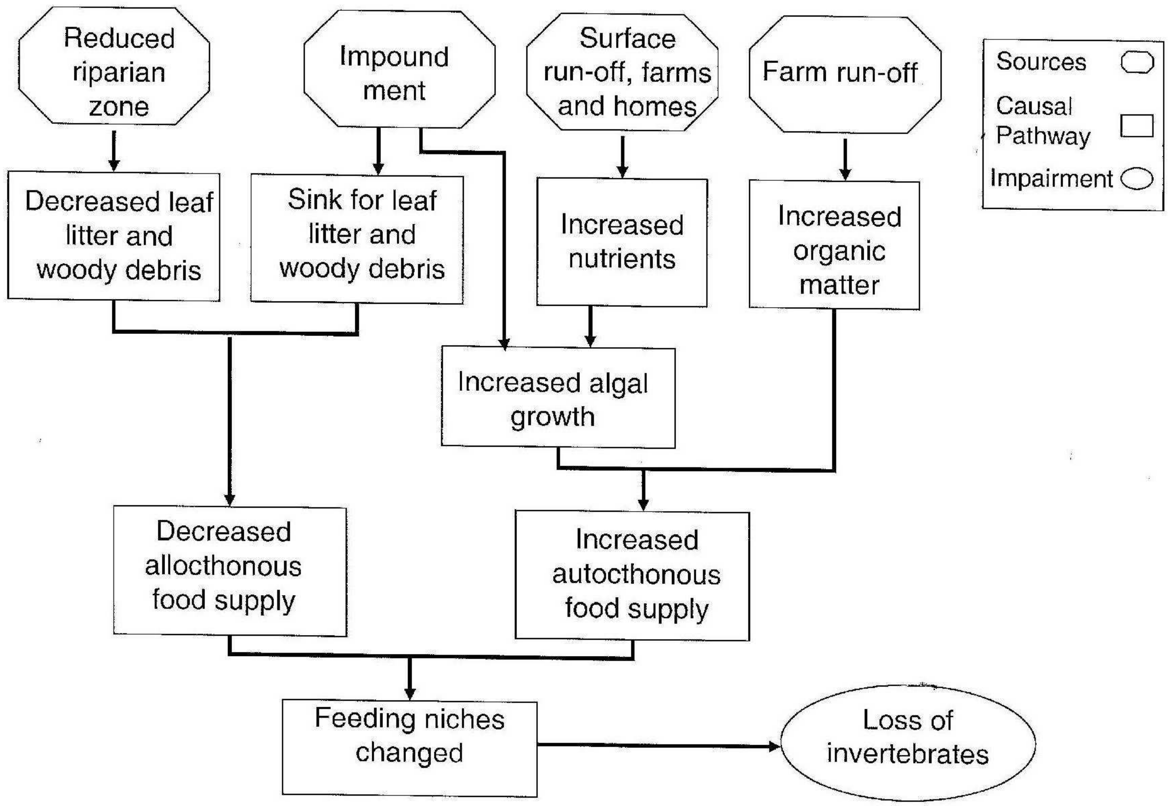
3.1.3 Stressor – Response Relationship

The process and methods used to develop nutrient criteria are ideally based upon a known and quantifiable stressor – response relationship. The stressor(s) "causes" the manifestation of the response or an "effect." The response or effect is some condition which fully or partially prevents the intended beneficial use(s) of the aquatic resource. The anticipated stressor-response relationships for lotic and lentic systems are discussed within Section 3.2. The preference is to establish criteria as an expression of the stressor variable where exceedance of some threshold results in an undesirable condition for the response variable.

Expectations are that conceptual ecological models (e.g., Causal Analysis / Diagnosis Information System or CADDIS; existing ecosystem water quality models) will provide the theoretical foundation for the stressor – response relationships. Example models are presented in the specific sections pertaining to lotic and lentic systems. Conceptual models will assist not only with identifying the stressor – response relationship, but also to reasonably ensure the proper stressor variables and metrics are identified and measured which best describe the system's response to nutrient enrichment.

Figure 1 shows an example conceptual model for a lotic system from CADDIS. There are several additional sources for conceptual models that can be used for lotic systems. Some of these conceptual models include commonly used receiving water quality models such as QUAL2K, CEQUALW2 and WASP. Prior to selecting specific stressor – response variables for developing the nutrient criteria for lentic systems, a conceptual model using currently available information will be finalized. Ideally, this conceptual model will recognize the uniqueness of the prairie aquatic ecosystem.

Figure 1. Example Conceptual Model for the Response of a Lotic System to Excess Nutrients (from CADDIS).



3.1.4 Water Body Classification

3.1.4.1 Classification System

The biological response to excess nutrients varies depending upon the physical and hydrologic characteristics of a water body. The actual metrics used to quantify the physical and hydrologic characteristics can vary. However, the metrics often involve an expression of light penetration, flow regime, and abiotic factors such as habitat, salinity, or acidity. Classifying water bodies is intended to enable the development of nutrient criteria which best reflects the likely response of water bodies which are similar in nature.

For the purpose of developing nutrient criteria, a process is needed to classify water bodies with regard to their landscape setting and the resulting physical and chemical characteristics within each geographic area. Based upon preliminary considerations, the following water body classification system is recommended:

Reservoirs and Lakes (Lentic Systems)

- a. Reservoir
    - i. Large River Reservoirs (e.g., Lake Sakakawea, Lake Oahe, Jamestown Reservoir, Lake Ashtabula)
    - ii. Small and Medium River Reservoirs (e.g., Sweet Briar Dam, McDowell Dam, Crown Butte Reservoir)
- b. Natural Lakes
    - i. Shallow Lakes (e.g., Lake Haskins, Green Lake, Powers Lake)
    - ii. Non-shallow Lakes (e.g., Devils Lake)
- c. Wetlands[4]

2. Rivers and Streams (Lotic Systems)
    - a. Perennial
        - i. Wadeable
        - ii. Non-wadeable (i.e., large)
    - b. Intermittent / Ephemeral

The recommended approach for classifying lentic water bodies includes using mean depth (derived from surface area and volume), maximum depth, fetch, open water area, overflow rate, and hydraulic residence time. The availability of some of these characteristics for lakes managed by the North Dakota Game and Fish is shown in **Map 7**. Hydraulic residence time and overflow rate may be derived using surrogates such as mean annual runoff volume derived from contributing drainage area. Two other important metrics, which may be considered or developed in the event the proposed

[4] Wetland nutrient criteria are not included in the scope of this Plan.

metrics are insufficient to classify lentic systems, are the mixing characteristics (e.g., polymictic versus dimictic) and dominant stable state (vis-a-vis clear macrophyte dominated state for shallow lake systems).

The recommended approach for classifying lotic water bodies includes the metrics of flow regime (likely frequency and magnitude of discharge) and drainage area at the watershed mouth. The National Hydrography Dataset (NHD) is anticipated to be the primary tool for the initial classification of lotic systems. A careful evaluation of the decision process used to define a stream within the NHD as perennial or intermittent is needed to ensure the distinctions between lotic systems (perennial and intermittent) are appropriate and suitable for nutrient criteria development within North Dakota. An alternative classification metric, which proved to be useful in Montana, is stream order.

The ability to develop nutrient criteria using the preliminary water body classification system depends upon the amount of water quality data available for the parameters of interest. Subsequent analysis of sample size by geographic area and water resource type is needed.

3.1.4.2 Definitions

The following preliminary definitions are presented for the purpose of classifying water bodies and determining the amount of water quality data available by water body type. These definitions may be modified or adjusted during the implementation of this plan.

Lentic Systems - Lentic systems are generally considered as standing water systems. This concept is quite broad, encompassing bodies of standing water with widely differing spatial (size) and temporal (seasonal) characteristics. In natural systems, there are no clear boundaries between standing water systems - only gradients. The categories and labels used to describe features such as wetlands, ponds, and lakes are somewhat arbitrary, often informal, and are primarily constructed to help manage the standing water systems. For this plan, a lentic system will include a lake, reservoir or wetland.

Lake - The State of North Dakota does not have a definition of a lake within the Century Code[6]. For the purpose of this plan, the following criteria are used to distinguish a lake system from other lentic systems:

1. Surface area of 10 acres (4 hectares) or more;
2. A maximum depth which is not less than 3.3 feet (1 meter); and
3. A minimum non-vegetated, contiguous open water area of 1,000 m^2 or more.

The standing water forming a lake is not artificially created or increased in depth by obstructing a watercourse through the use of a dam or other man-made obstruction.

Shallow Lake - A shallow lake is a natural lake, characterized by standing water, where light penetrates to the bottom sediments to potentially support rooted plant growth throughout the water body. The lack of consistent thermal stratification during

[6] The Century Code is the codification of all general and permanent law enacted since statehood.

the summer and the tendency to exhibit alternative turbid and clear stable states are also common characteristics of this class of water.

Non-shallow Lake - A non-shallow lake is characterized by both a shallow shoreline area that may potentially support rooted plant growth and a deeper portion where sunlight does not penetrate to the bottom. These water bodies frequently stratify into distinct thermal layers during the summer.

Reservoir - Reservoirs are artificial (man-made) lentic systems. At a minimum, reservoirs must meet the first three conditions defined for a lake system. In addition, the following criteria are used to distinguish reservoirs from other lentic systems:

1. Existence of a control structure to actively regulate water levels and discharge; and
2. Generally shorter hydraulic residence time (generally less than 1 year) because of a larger drainage area to surface area ratio compared to a lake.

Wetland **–** A lentic system that is inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and that under normal circumstances does support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs and similar areas.

Lotic systems **–** Lotic systems are generally flowing water systems. More specifically, they can be characterized by the presence of a unidirectional gravity induced current. As with lentic systems, there is substantial variability in the types of lotic systems. For this plan, a lotic system will include wadeable and non-wadeable streams or rivers.

Wadeable Stream or River - A wadeable stream or river is a lotic system which can generally be traversed on foot and exhibits a depth such that it can be “sampled” without the use of a boat during summer base flow conditions. These lotic systems can be further classified according to the temporal nature of their flow regime as either perennial or intermittent.

Non-Wadeable Stream or River - A non-wadeable stream or river is a lotic system which can not be traversed on foot and exhibits a depth such that “sampling” can only be conducted with the use of a boat during summer base flow conditions. These lotic systems are typically perennial.

Perennial Stream or River - These systems are generally considered those which have flowing water throughout most of the year during the open water season (generally > 90% of the time) during a typical year. These systems may periodically have no observable flow, but this generally occurs only during extreme drought. The stream bed seasonally intersects the water table. Groundwater is typically the source of base flow and runoff from rainfall is a supplemental source of water for stream flow. Perennial streams and rivers are generally 3rd order or greater.

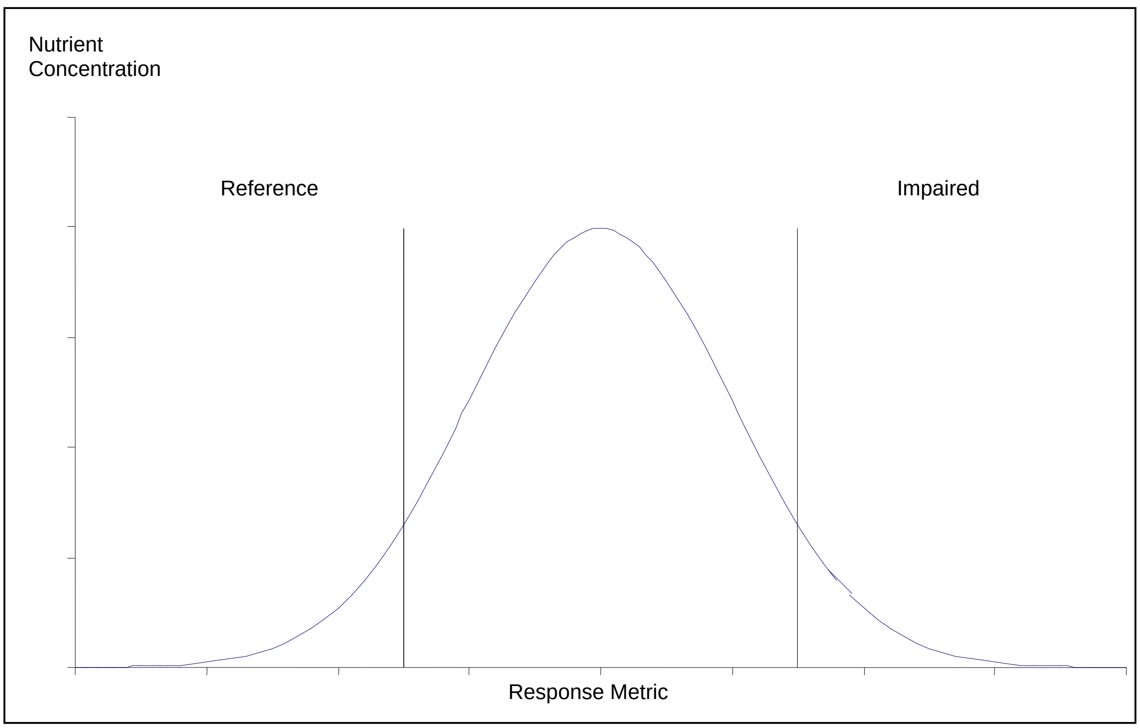
Intermittent Stream or River - These systems are generally considered those which only periodically have flowing water during the open water season, during most years. These systems may not convey water at all, unless under periods of extremely high precipitation. The stream bed seasonally intersects the water table. Runoff from rainfall is a supplemental source of water for stream flow. These streams and rivers may be 2nd, 3rd or 4th order.

Ephemeral stream: An ephemeral stream has flowing water only for a short duration during spring runoff or after precipitation events in a typical year. Ephemeral stream beds are located above the water table year-round. Groundwater is not a source of water for the stream. Runoff from spring runoff or rainfall is the primary source of water for stream flow. An ephemeral stream is generally 1st or 2nd order.

3.1.5 Criteria Variability and Beneficial Use Impairment

The purpose for developing regional nutrient criteria is to broadly protect water bodies from the enrichment of nutrients due to human effects, thereby protecting designated beneficial uses (e.g., recreation, drinking water supply, aquatic life). Nutrient concentrations within a water body fluctuate across some range in response to naturally occurring factors such as varying loads resulting from a range of precipitation and runoff conditions. The biological response will mirror this natural fluctuation. It is expected that water bodies in "ecological balance" can experience a range of nutrient concentrations (either daily, seasonally or annually), while still supporting beneficial uses. The regional nutrient criterion must also either implicitly or explicitly incorporate an acceptable range of concentrations bounding that criterion. This concept is graphically shown in **Figure 2**. Conceptually **Figure 2** illustrates that opposing ends of a

Figure 2 – Conceptual Distribution of Chemical Concentrations within Water Bodies across a Geographic Area and the Relationship Between a Nutrient Criterion, and Reference and Impaired Conditions.*



*Represents the concentration "population" from all measured sites. Adapted from Figure 9 in EPA 2000.

response metric frequency distribution are the reference water bodies (low nutrient enrichment) and impaired water bodies (high enrichment).

Finding locations which represent reference conditions can be challenging. Most of the state's land cover is altered and affected by human influence. Caution is needed to properly define and characterize reference, if this approach is used to establish nutrient criteria (see Section 3.1.6 for the definition of reference).

A nutrient criterion is not intended to represent a single threshold from which beneficial use impairment can be determined. A criterion is a regionally-derived value based upon the classification of several or many similar water bodies. The process to ascertain beneficial use impairment is procedurally more rigorous in North Dakota. A common thread is that some of the stressor variables are the same as the core and supplemental indicators, which the State uses in beneficial use determination.

The nutrient criteria, once established, are based on regional information intended to establish maximum acceptable nutrient levels for water bodies of different types across the State. The NDDH uses additional factors to list specific waters as impaired and place them on the Section 303(d) list of impaired waters needing TMDLs. For those water bodies which are impaired by nutrients, a specific total maximum daily load study (TMDL) must be performed to determine how a water body can be improved (i.e., nutrient levels reduced) to meet its beneficial uses. It should be recognized that there may be the need on a site specific basis (i.e., TMDL where the regional criteria are not sufficient, either too restrictive or not restrictive enough) to establish site specific criteria. In these cases, the site specific criteria will be adopted into the State's water quality standards prior to TMDL implementation.

It is recommended that there also be a process to evaluate and define a translator mechanism during the nutrient criteria development process. This translator mechanism would allow established nutrient criteria to be adjusted in order to address impaired water bodies. The translator mechanism would essentially be a method or process allowing the "conversion" from the numeric criteria developed for a region to a site specific criteria or goal.

3.1.6 Reference Condition Definitions

A wide range of definitions have been used to describe reference condition. Ideally, a location selected to represent reference conditions reflects pristine conditions, devoid of any human influence. The following definitions are applicable to developing nutrient criteria:

Pristine - The biological condition exhibited by an aquatic resource in absence of human disturbance, as characterized by the types and abundance of species. The biological condition prior to Euro-American settlement is generally assumed to be "pristine".

Minimally Impacted Conditions - The biological condition exhibited by an aquatic resource in the presence of minimal human disturbance, as characterized by the types and abundance of species. The biological condition following Euro-American settlement is generally assumed to be impacted. An analysis of the condition of the landscape within the contributing drainage area is typically characterized by minimal agricultural and urban influences. It is generally assumed that these conditions do not actually occur in North Dakota.

Least Impacted Condition - The biological condition exhibited by an aquatic resource characterized by the least amount of human disturbance available in a region for a water body class, as characterized by the types and abundance of species. The definition of least impacted conditions has the same meaning as "regional reference site" as defined within 2.b.(6) of 33-16-02.1-08 General Water Quality Standards of North Dakota Century Code. The biological condition following Euro-American settlement is generally assumed to be impacted. An analysis of the condition of the landscape within the contributing drainage area is typically characterized by the smallest amount of agricultural and urban influences. The least impacted condition may or may not be the minimally impacted condition.

Regional reference sites (2.b.(6) of 33-16-02.1-08 General Water Quality Standards of North Dakota Century Code) means sites or water bodies which are determined by the department to be representative of sites or water bodies of similar type (e.g., hydrology and ecoregion) and are least impacted with respect to habitat, water quality, watershed land use, and riparian and biological condition. Regional reference sites are used to describe regional reference condition.

Using the least impacted reference condition to establish the nutrient criteria is recommended.

Efforts are ongoing within the State to establish a suite of candidate reference sites and/or reaches, which can be used for multiple purposes, including the development of biological criteria, suspended and beded sediment (SABS) criteria, and **nutrient criteria**. The EMAP Western Pilot Project effort identified 21 reference sites within a single Level III ecoregion for North Dakota (see **Table 11**). Further identification of reference sites are expected as part of a planned biological monitoring effort for the Red River of the North Basin, catalyzed by the International Red River Board (IRRB) (Fritz 2004). Recommended definitions of reference conditions as developed for the IRRB are similar to those described above. The NDDH anticipates establishing a reference site network, with one of the purposes being the development of nutrient criteria. Important data to be collected at the reference sites include nutrient concentrations and cause-affect relationships for nutrient response.

3.2 Recommended Approaches for Nutrient Criteria Development

The preliminary recommendations are based upon the current understanding of data availability, the desired philosophy of the NDDH, and the need for a method tied to the biological response of the resource to excess nutrients. The approach ultimately selected and implemented may be different from that recommended, as additional information and data are collected and analyzed. The approach ultimately selected must result in nutrient criteria which are technically and scientifically defensible, can be reasonably implemented within state law and rule, and are acceptable to society. *Preliminary* *recommended approaches are provided for lotic and lentic systems separately, because of their differing response to excess nutrients.*

3.2.1 The "EPA Approach"

As stated in Section 1.2, the EPA outlines three approaches from which States could develop their nutrient criteria. The first two approaches are based on descriptive statistics defining the 75th percentile concentration for reference sites, or the 25th percentile concentration of non-reference sites, to identify the numeric criterion for a parameter. Regionally recommended nutrient criteria by the EPA are summarized in **Table 12**, along with criteria based on previous North Dakota analyses. *The use of statistical methods and the selection of percentile concentrations as an approach for determining nutrient criteria are not recommended for North Dakota, without some linkage to the stressor-response relationship*. Noteworthy drawbacks to a purely statistical based method include:

- Percentiles of data do not consider the environmental context of a resource. For instance, this method would apply the same numeric criterion to all perennial streams, regardless of size (e.g., Missouri River versus the Maple River);
- The "arbitrary" choice of a percentile rank may in fact establish a numeric criterion lower than the least impacted or minimally impacted conditions; and
- Use of a statistically based approach is not tied to the stressor-response relationship, and does not address the ability of a percentile-derived criterion to protect beneficial uses.

While the EPA technical guidance manuals provide excellent information, they do not specifically relate the recommended approach to the beneficial use. These uses vary from state to state. As noted in Section 2.3, North Dakota recognizes four beneficial uses for water bodies. *This plan for developing criteria is based upon establishing nutrient criteria protecting the most "stringent" beneficial use, which in most cases will be aquatic life. The recommended approaches assume that criteria developed to be protective aquatic life are also protective of all other beneficial uses (e.g., drinking water supply, recreation).*

3.2.2 Proposed Approach for Lentic Systems

3.2.2.1 Conceptual Model

Figure 3 presents a conceptual ecological model showing the response of lentic systems to excess nutrient concentrations. This model suggests potential causative ecological endpoints (i.e., response variables) include the frequency and severity of algal blooms, the concentrations of chlorophyll-a and chlorophyll-b, some measure of water clarity, dissolved oxygen concentrations and Trophic Status Index (TSI) score. The conceptual model further suggests that the applicable causative variables are those that limit primary production.

3.2.2.2 Ecological Endpoints (Response Variables)

The response variables are generally those variables measured in the environment that are used to determine whether a resource is impaired because of excess nutrients. During the process of developing nutrient criteria, the response variables will be used to develop the “cause – affect” relationship that forms the technical basis for the criteria.

Several ecological endpoints are used by the NDDH in assessing impairment and the attainment of beneficial uses for aquatic life. The ecological endpoints are also our response “targets” for the nutrient criteria. Characteristics of the fish community (primarily the types and abundances of species) and the algal community (primarily characterized by the types and abundances of phytoplankton and the amount of chlorophyll) are often used as ecological endpoints.

An increase in the frequency and severity of algal blooms is a typical response to excess nutrients in lakes and reservoirs. Algal biomass, expressed as the concentration of the pigment chlorophyll-a, is a common variable used to assess the response of lakes and reservoirs to excess nutrients. Algae in the water column reduce water clarity and the penetration of light. Secchi disk transparency, an indicator of water clarity, is an excellent physical response variable.

Using the concentrations of chlorophyll-a and chlorophyll-b, and water clarity expressed as Secchi disk transparency, as the response variables for nutrient enrichment is recommended. An additional recommendation is that the frequency and severity of algal blooms be evaluated as a potential response variable. This requires operationally defining an “algal bloom.” The definition of a bloom likely varies geographically, depending upon user perception.

Because the fish community is dependent upon suitable physical and chemical conditions for survival, we further recommend that dissolved oxygen be considered as a response variable. The amount of dissolved oxygen available to support a diverse assemblage of fish species generally declines as the severity of nutrient enrichment increases.

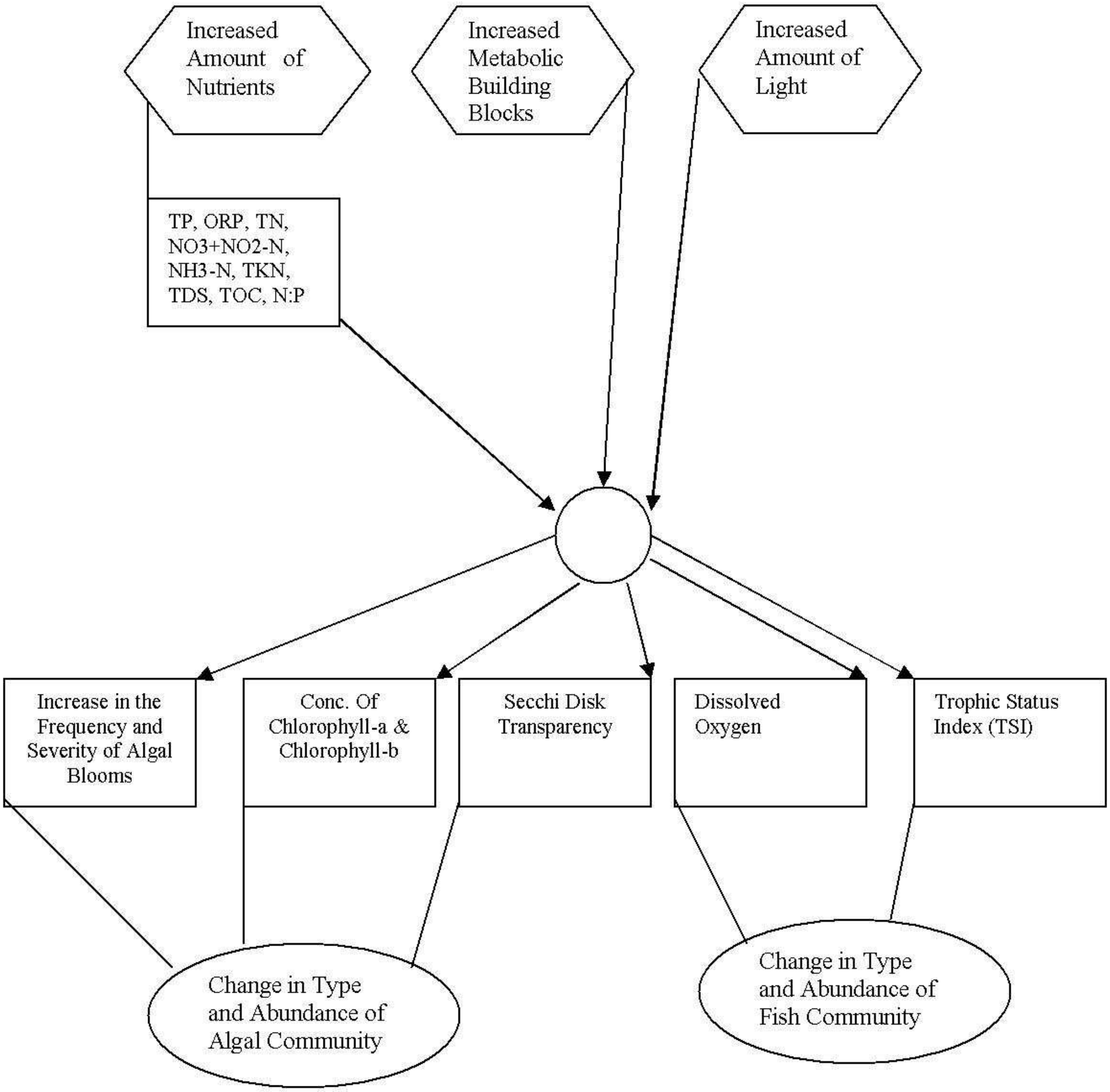
3.2.2.3 Causative Variables as Nutrient Criteria

Nutrient enrichment is principally responsible for: 1) changes in basic food webs including altered algal communities and causing harmful or nuisance algal blooms, which can lead to the loss of an economically important fishery and overall aquatic biodiversity; 2) loss of native submerged aquatic plant habitats that are important to fish and other biota; and 3) anoxia leading to fish kills and/or degraded benthic (bottom) habitats that affect shellfish and other biota.

The key in developing nutrient criteria is to understand the specific factors that biologically limit algal production. Those variables measured in the environment, which are indicative of excess nutrients, and that drive the ecological response are potential causative variables that can serve as criteria.

Lentic systems are known to respond to: 1) increasing concentrations of various nutrients including nitrogen and phosphorus; 2) increasing concentrations of metabolic building blocks, including various forms of carbon (e.g., CO_2) and silica; and 3) light needed for photosynthesis. The mathematical form of the response may be linear or nonlinear.

Figure 3 – Conceptual Ecological Model for the Response of a Lentic System to increased Nutrient Concentrations (from CADDIS).



An initial evaluation of the following causative variables as potential nutrient criterion is recommended:

- Total phosphorus
- Orthophosphate or dissolved phosphorus
- Total nitrogen
- Nitrate plus nitrite nitrogen
- Nitrogen to phosphorus ratio
- Ammonia nitrogen
- Total Kjeldhal nitrogen
- Total organic carbon
- Dissolved organic carbon
- Total dissolved solids

The use of an indicator like the Trophic Status Index (TSI), which combines several trophic characteristics, should also be considered. Statistical analysis of the response and causative variables will be used to select the final parameters. Those parameters which have the strongest predictive relationship with the ecological endpoints will be the most useful to establish as criteria. Confounding factors such as salinity concentrations should be incorporated into the analysis to determine if modifications to the lentic system classification method are needed.

Expectations are that a detailed analysis of the various forms of nitrogen is not needed. Rather, the response to total nitrogen or inorganic nitrogen may be sufficient to describe the response of the ecological system.

3.2.2.4 Temporal Scale

Use of the open water season is recommended as the temporal scale for the development of nutrient criteria in lentic systems. The specific temporal scale over which nutrient criteria are applied should be confirmed during the course of nutrient criteria development. Potential options for the temporal scale include the growing season (April 1 – October 31), summer season (roughly June 1 – September 1), or recreational season (May 1 – September 30).

3.2.2.5 Spatial Scale

Use of the average water column concentration taken in the deepest (often middle) portion of a lake or reservoir is recommended as the spatial scale for the nutrient criteria. An alternative approach is expressing the criteria as a value representative of the surface mixed layer. Horizontal variation in larger lakes and reservoirs is also likely. Therefore, for larger lakes and reservoirs the nutrient criteria may need to be established longitudinally or for specific embayments.

3.2.2.6 Recommended Criteria Development Method

One important guiding principle is that the nutrient criteria should ideally be based on a definable cause – effect relationship. *The recommended approach for developing nutrient criteria for lakes and reservoirs is based on establishing regionally defensible cause (i.e., load) – effect (i.e., eutrophication response) relationships*. These relationships should incorporate the important causative and response variables and ideally incorporate the frequency and duration of the conditions causing beneficial use impairment (e.g., algal bloom frequency and duration). The approach requires establishing a threshold defining an “algal bloom” correlated to the impairment in aquatic life (or another beneficial use such as recreation).

Figure 4 presents the recommended method for developing the nutrient criteria for lakes and reservoirs. Expectations are that the method would be applied using appropriate spatial and temporal scales. The approach is based upon developing and applying regional eutrophication load-response models, tied to dissolved oxygen levels and the impact to aquatic life. The approach depends upon the ability of the NDDH to establish eco-region appropriate lake and reservoir trophic goals. These goals may be established based upon reference conditions, or the desired trophic state using best professional judgment. The approach essentially consists of using models to “back-calculate” regional nutrient loads based upon the established goals. The regional model will need to be applied on a geographically representative sample of lakes and reservoirs to establish the regional load. The regional load will then require translation into concentration or yield for some distance upstream, while considering the appropriate runoff conditions (e.g., average runoff year). The recommended criteria developed using this technique needs to be compared to the method developed for lotic systems, with the most stringent applied.

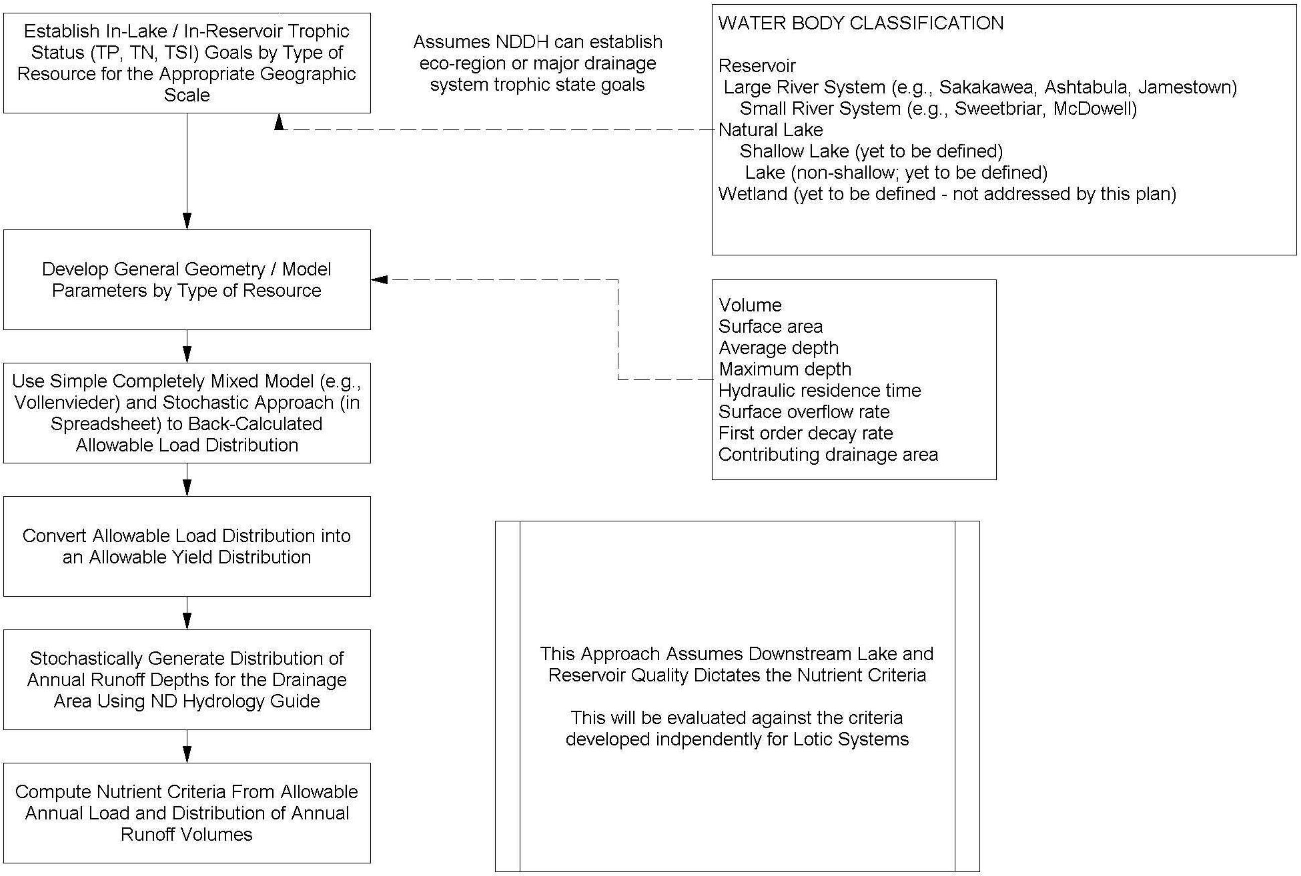
An alternative method may be used if the ability to establish goals using the desired trophic state or data limitations prohibits the use of the recommended method. The alternative approach is the use of descriptive statistics for the concentrations of the causal variables correlated to the response condition leading to beneficial use impairment. This approach is more fully described in Section 3.2.3.6 and is the recommended approach for lotic systems.

3.2.2.7 Data Gaps and Potential Issues

A significant issue for North Dakota is the lack of monitoring data relating to lakes which reflects reference conditions. The EPA is undertaking a National Lake Survey utilizing a probabilistic site selection approach, so it is possible that this gap may be addressed through pending efforts. However, four groups of lentic systems are proposed for North Dakota’s nutrient criteria, so any data reflecting expected condition may only apply to certain types of lentic systems (e.g., shallow lake).

Another data gap is the lack of a Trophic Status Index (TSI) model specific to the state. Carlson’s TSI model is currently utilized by the NDDH to assess eutrophication in lentic systems. A major drawback to using Carlson’s TSI is that it was developed for lakes that are primarily phosphorus limited. Because most North Dakota lakes and reservoirs have an abundance of phosphorus, this model should be modified or otherwise adapted for conditions in North Dakota to provide a tool to establish causative variable criteria from endpoints such as Secchi depth transparency.

Figure 4. Potential Process to Establish Nutrient Criteria for Lakes and Reservoirs.



An additional challenge is how to convert a regionally defined load into nutrient concentrations in the streams and rivers entering the lake or reservoir and how to modify the concentrations moving upstream in the drainage area. Much of the available data is more than 5 years old, and therefore has been subject to varying and changing data collection and analytical techniques. While the National Lakes Survey will assess lakes statewide, only a single measurement will be collected from each lake. Additional funding could be used to sample the National Lakes Survey lakes additional times, sufficient to develop cause – affect relationships.

Table 16 shows the availability of paired nutrient concentration data (i.e., causual variable) and differing potential response variables, by monitoring effort / program and ecoregion for lentic and lotic systems. Considerable paired total phosphorus, total nitrogen and chlorophyll-a data are available within the NDDH database for lentic systems, with the exception of Level III ecoregion 48. No chlorophyll-a data are available within the remaining datasets for lentic systems. The NDDH data should initially be used to evaluate potential cause – affect relationships. Further analysis of the data is needed to determine sample sizes by water body type.

3.2.3 Proposed Approach for Lotic Systems

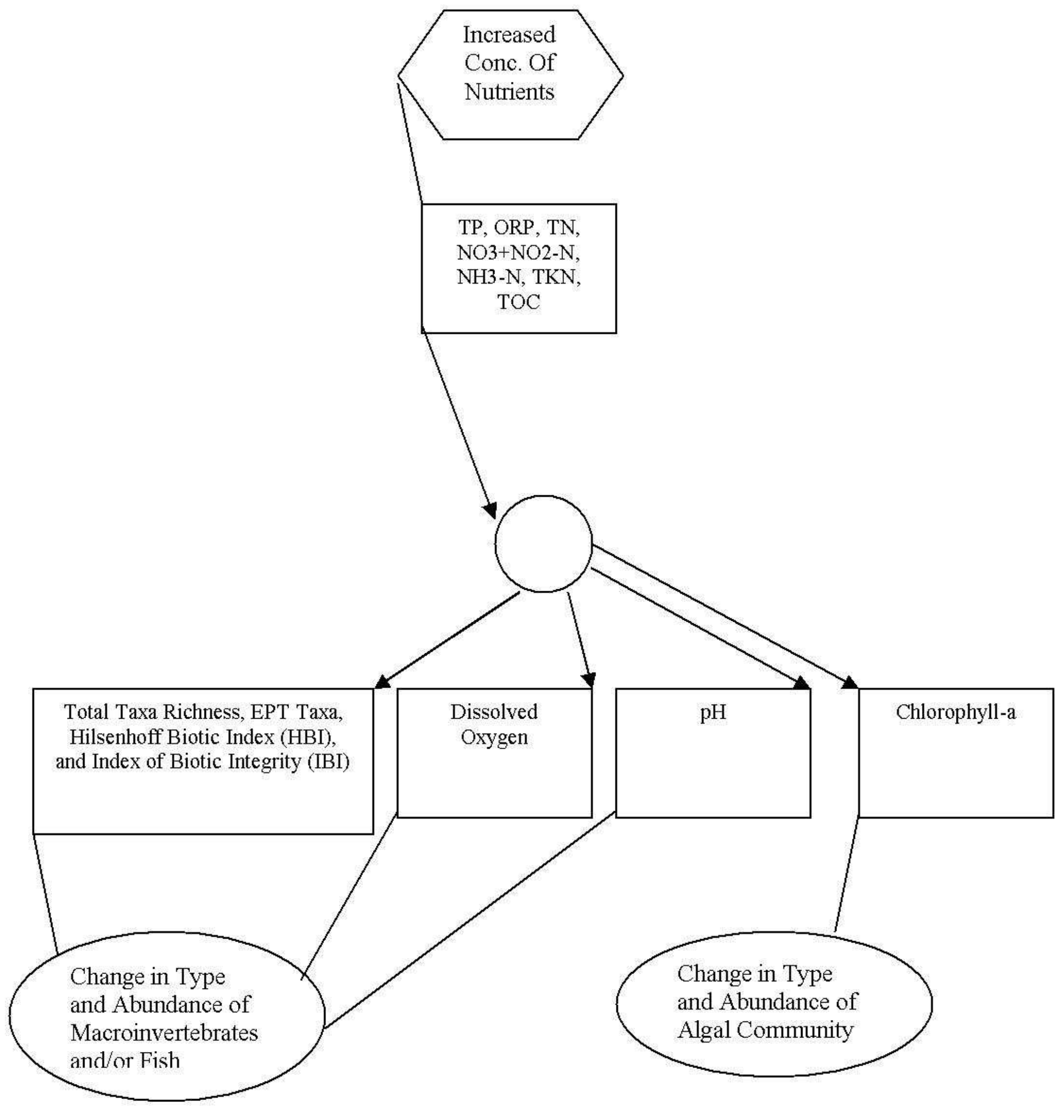
3.2.3.1 Conceptual Model

Figure 5 presents a conceptual ecological model showing the response of lotic systems to excess nutrient concentrations. This model suggests potential ecological endpoints (i.e., response variables) include the frequency and severity of algal blooms, the concentrations of chlorophyll-a, and various metrics associated with the aquatic community (e.g., fish, macroinvertebrates, periphyton). The conceptual model further suggests that the applicable causative variables are those that limit primary production.

3.2.3.2 Ecological Endpoints (Response Variables)

Several ecological indicators are used by the NDDH in assessing whether a stream or river attains the beneficial use for aquatic life. The ecological endpoints are also our response “targets” for the nutrient criteria. These ecological endpoints include the macroinvertbrate assemblage, the types and abundance of fish, the algae and diatom assemblages and plant biomass as characterized by macrophyte density and algal biomass (epiphyton, periphyton, phytoplankton). The pigment chlorophyll-a is typically used to quantify algal biomass. Excess nutrients, through biological processes, can also affect the magnitude of and daily variation in the amount of dissolved oxygen.

Figure 5 – Conceptual Ecological Model for the Response of a Lotic System to Increased Nutrient Concentrations (from CADDIS)..



Provided light (or some other physical or chemical characteristic) does not limit primary productivity, an excess of nutrients within perennial rivers and streams leads to an increase in the biomass of epiphytic algae. The increase in epiphytic algae is generally less in turbid lotic systems than in those with less turbidity. Understanding the response to excess nutrients within intermittent streams is less clear and therefore, will be more challenging.

Ecological endpoints typically include some characteristic of the ecological community, population distribution or dynamic, or the abundance and distribution of specific organisms. For example, the EPT (*Ephemeroptera* + *Plecoptera* + *Trichoptera*) taxa richness metric is one common characteristic of the macroinvertebrate community used to assess whether a stream or river is meeting its beneficial uses. The EPT characteristic or “metric” is simple, known to be stable at reference sites or reaches, and can be used to effectively evaluate changes in water quality. The EPT taxa metric proved useful on the Sheyenne River in earlier work completed by the NDDH (Zheng et al., 2005).

Macroinvertebrate sampling in wadable streams within North Dakota is extensive. The NDDH performs macroinvertebrate sampling through: 1) pilot projects such as through the EMAP Western Pilot Project; 2) on the Sheyenne River to characterize macroinvertebrate structure; 3) a rotating basin bioassessment program approach to monitoring which is now being applied within the Red River Basin; and 4) Section 319 Nonpoint Source Pollution watershed assessment projects. While there are substantial efforts to characterize ecological endpoints, the variability within the available data presently makes it uncertain as to which metric will best reflect the response of a stream to human impacts and changes in nutrients.

Various macroinvertebrate endpoints or metrics are recommended as the response variables for excess nutrients within rivers and streams (based upon a conceptual model). These metrics may include total taxa richness, EPT taxa, the Hilsenhoff Biotic Index (HBI), and the Index of Biotic Integrity (IBI). Algal biomass, the concentration of dissolved oxygen, and pH may also be evaluated as potential response variables. The use of macroinvertebrate endpoints is consistent with the Sheyenne River pilot study.

3.2.3.3 Causative Variables as Nutrient Criteria

As noted in Section 3.2.2.2, many efforts have been implemented to collect data on response variables. Similarly, data for numerous causative variables, including nutrients, have been collected over time. Cursory evaluations EMAP West Pilot project data and Sheyenne River Nutrient Pilot project data suggest that both total phosphorus and total nitrogen, respectively, can be related to changes in macroinvertebrate composition.

Lotic systems are known to respond to increasing concentrations of various nutrients including nitrogen, phosphorus; the metabolic building block carbon (e.g., CO_2); and light. The nature of the response may be linear or nonlinear.

An initial evaluation of the following causative variables as potential nutrient criterion is recommended:

- Total phosphorus
- Orthophosphate or dissolved phosphorus
- Total nitrogen
- Nitrate plus nitrite nitrogen
- Ammonia nitrogen
- Total Kjeldhal nitrogen
- Dissolved organic carbon
- Total organic carbon

Statistical analysis of the response and causative variables based upon the conceptual model will be used to select the final parameters. Those parameters which have the strongest predictive relationship with the ecological endpoints will be the most useful to establish as criteria. Expectations are that a detailed analysis of the various forms of nitrogen is unneeded. Rather, the response to total nitrogen or inorganic nitrogen is sufficient to describe the response of the ecological system.

3.2.3.4 Temporal Scale

Defining the temporal scale for the nutrient criteria can help guide future data collection efforts. There are several options for defining the temporal scale for lotic system nutrient criteria, including daily, weekly, monthly, seasonal, and annual (load based). The temporal scale will depend in large part on whether the lotic system is perennial or intermittent. The magnitude of nutrient concentrations during base flow will differ inherently from those occurring storm or event flows. When determining the temporal scale of the nutrient criteria, the frequency of in-stream concentrations and the duration over which the concentrations occur should be considered.

The nutrient criteria may need to consider a weekly or even shorter temporal scale if dissolved oxygen or pH is used as the response variable(s). Excess nutrients can lead to increased epiphytic algae and an increase in the amplitude of the diel variation in dissolved oxygen. Low dissolved oxygen during the early morning in some streams and rivers can lead to aquatic life impairment.

3.2.3.5 Spatial Scale

Expectations are that the nutrient criteria will be developed by Level III ecoregion and major drainage basin and separately for perennial and intermittent streams and rivers. Further separation of the large non-wadable river systems like the Missouri River and Red River from other non-wadeable perennial streams is likely. Nutrient criteria for the Missouri River will likely be developed in cooperation with upstream and downstream states (e.g., Montana, South Dakota, Iowa, Kansas, Nebraska, Missouri), while criteria for the Red River will likely involve a collaborative effort with Minnesota and the province of Manitoba.

3.2.3.6 Recommended Criteria Development Method

The use of a reference approach to establish the nutrient criteria for lentic systems is recommended. The recommended approach consists of:

1. Refining the conceptual model **(Figure 5**) for each lotic system of interest (i.e., intermittent and perennial wadeable and non-wadeable streams) to reasonably ensure the identification of the stressor and response variables, as well as the causative mechanism for the response to excess nutrients and the ecological endpoints;
2. Using existing or newly collected biological data (e.g., fish population characteristics, macroinvertebrate abundance / diversity, periphyton abundance / diversity) to test / validate the ecological endpoints described by the conceptual model. Use the reference sites to establish the desired conditions for the ecological endpoints;
3. Subdivide the resource according to the appropriate water body classification for lotic systems;
4. Use landscape scale features to identify candidate reference sites[7] or reaches, stratified by Level III ecoregion and major drainage basin, which represent least impacted conditions and the nutrient condition gradient. Previous work completed in the Sheyenne River Basin suggests that less than 60% of the upstream land use in agriculture is necessary to define a site or reach as "reference." Additional analysis will be needed to confirm this early conclusion;
5. Evaluate the ability to use various surrogate response variables across the nutrient gradient, for the ecological endpoints of interest (e.g., relate pH and dissolved oxygen dynamics to the ecological response endpoints);
6. Use existing or newly collected chemical concentration data, specifically for the causative variables (as discussed in Section 3.2.3.3), and evaluate potential statistically significant relationships between the causative variable (stressor) and the various fish, macroinvertebrate, and periphyton ecological endpoints (i.e., response variables);
7. Determine the ecological endpoint(s) which best supports criteria development; and
8. Establish nutrient criteria for causative variables based on thresholds established for the ecological endpoints;

Two additional steps may be completed, should the recommended approach prove challenging:

9. Compute descriptive statistics (including the 85^{th} percentile values) for the causative variables at various temporal scales. In the absence of statistically significant relationships between the causative and response variables, anecdotally identify the relationship between the descriptive statistics for the

[7] The reference approach takes into account a range of disturbances defined as least impacted and, therefore, a range in the stressor-response relationship.

causative and response variables. Use this anecdotal information to establish the nutrient criteria. Work completed by the Department of Environmental Quality in Montana has shown the 85th percentile to be correlated to reference conditions when using biological metrics.

10. In the absence of a definable relationship, use the 85th percentile concentration for the reference condition.

3.2.3.7 Data Gaps and Potential Issues

A potential issue relates to situations when lotic systems discharge into lentic systems. The criteria set forth to protect the beneficial uses in a particular river or stream reach may not necessarily also be protective for conditions in downstream resources (i.e., a lake or reservoir). The role of a translator mechanism as discussed in Section 3.1.5.1 is important in this context. This would potentially allow for adjustments (i.e. more stringent) to nutrient criteria in lentic systems such that it would "agree" with the criteria established for lotic systems, thus protecting the beneficial uses in both systems.

A second substantive issue is the availability of fish, macroinvertebrate and periphyton data needed to develop the various response variable metrics. These data need to be specific to reference sites or reaches and across nutrient gradients within the geographic region of interest. Based upon a cursory review of the available macroinvertebrate data, additional data will need to be collected for reference reaches.

Large non-wadeable river systems (e.g., the Missouri River, and lower Red River) present unique technical challenges requiring a set of causative variables which may be different than for smaller wadeable perennial systems. Large river system ecology can differ considerably from smaller systems. These challenges include how reference conditions are defined, sampling challenges and a generally greater importance of allocthanous than autocthanous energy inputs. The need to collaborate with other state, provincial, and federal agencies will also be a challenge.

Table 12 shows the availability of paired nutrient concentration data (i.e., causual variable) and differing potential response variables, by monitoring effort / program and ecoregion for lotic and lentic systems. Little paired total phosphorus, total nitrogen and chlorophyll-a data are available within the NDDH database for lotic systems. Samples sizes exceeding 30 are available for select ecoregions within the western EMAP database. Further analysis of the data is needed to determine sample sizes by water body type.

4 Implementation Priorities and Administrative Issues

4.1 Priority for Developing Nutrient Criteria

Developing nutrient criteria is expected to require a considerable level of effort both in terms of staff and financial resources. Due to limited staff and financial resources, the NDDH will need to develop nutrient criteria sequentially by water body type and geographic region. The priority for developing nutrient criteria has been established by the NDDH based on several considerations, including recreational importance, intensity of use as a fishery, regional or state-wide prominence, TMDL need, and/or quantity and quality of existing data for criteria development. *The following priority will be used for developing nutrient criteria within the State of North Dakota:*

1. Large reservoirs and deep natural lakes;
2. Shallow natural lakes, small reservoirs;
3. Perennial wadeable rivers and streams;
4. Perennial non-wadeable (large) rivers and streams;
5. Intermittent/ephemeral streams; and
6. Wetlands.

Developing nutrient criteria for most types of water bodies will likely require the collection of additional water quality and biological data. The priority may be revised based upon the availability of existing water quality data and TMDL development activities. Those water bodies with a greater amount of water quality data have also been given preference.

4.2 Data Needs

Many of the data needs have previously been identified within this criteria development plan. The most critical of these data needs include:

1. Geospatial landscape scale data sufficient to identify and select reference sites and reaches as well as impacted or disturbed sites (i.e., sites across the nutrient gradient);
2. Geometric and morphometric data for classifying water resources;
3. Hydrologic and runoff data to assist with classifying wadeable streams as intermittent or perennial and for the recommended lentic system approach. Discharge and runoff data should ideally be paired with the causative and response variables;
4. Sufficient data for the causative variables to be representative of the populations at reference sites and reaches; and
5. Sufficient data for the response variables to be representative of the populations at reference sites and reaches. These data should be "paired' with the causative variables.

A general rule of thumb is a sample size of 30 for establishing a statistical representation of the population. Therefore, a minimum of two to three years of effort is expected to obtain the minimum data needs for each waterbody type and geographic strata.

4.3 Administrative Requirements

North Dakota Century Code lacks many of the definitions needed to establish nutrient criteria. Preliminary definitions presented here and in subsequent documents will be refined for use in the promulgation of a final rule. There is no known obstacle to implementation of nutrient criteria through the North Dakota Century Code. As an initial step in the nutrient criteria development process, the state should consider establishing a narrative nutrient or eutrophication standard.

4.4 Schedule and Milestones

The schedule and completion of milestones is completely dependent upon sufficient staff and funding. The NDDH currently lacks sufficient staff and financial resources to implement all of the steps presented. Assuming that additional staffing and financial resources are available, an eight year process to completely develop and implement nutrient criteria seems plausible as follows.

Time Period	Milestone Activity
Year 1	• Develop conceptual models for each lentic water body type identified in Section 3.2.2.1. • Complete review and analysis of existing surface water quality monitoring data for lentic systems at the recommended spatial and temporal scales. • Modify current monitoring program design for lentic systems to fill data gaps and needs for criteria development. • Complete an evaluation of known lentic reference sites. • Complete additional Geographic Information System analysis to identify potential range of reference sites and other locations for lentic systems across the nutrient concentration and/or trophic status gradient. • Evaluate priorities recommended in this plan for criteria development and methods to reduce fiscal impact (e.g., implement by geographic region). • Develop detailed budget for developing the nutrient criteria for lentic systems.

Year 2

- Initiate data collection for priority one water bodies (large reservoirs and deep natural lakes) within all ecoregion / major drainage basin strata.
- Develop conceptual models for each lotic water body type identified in Section 3.2.3.1.
- Complete review and analysis of existing surface water quality monitoring data for lotic systems at the recommended spatial and temporal scales.
- Modify current monitoring program design for lotic systems to fill data gaps and needs for criteria development.
- Complete an evaluation of known lotic reference sites.
- Complete additional Geographic Information System analysis to identify potential range of reference sites and other locations for lotic systems across the nutrient concentration gradient.
- Evaluate priorities recommended in this plan for criteria development and methods to reduce fiscal impact (e.g., implement by geographic region).
- Develop detailed budget for developing the nutrient criteria for lotic systems.

Year 3

- Complete data collection for priority one water bodies (large reservoirs and deep natural lakes).
- Initiate data collection for priority two water bodies (shallow natural lakes, small reservoirs) within all ecoregion / major drainage basin strata.
- Test the methods recommended by this plan for priority one water bodies.
- Refine the methods and recommendations for developing nutrient criteria for priority one water bodies based upon data analysis and lessons learned.
- Apply the refined method to compute draft criteria for priority one water bodies.

Year 4

- Complete data collection for priority two water bodies (shallow natural lakes, small reservoirs) within all ecoregion / major drainage basin strata.
- Initiate data collection for priority three water bodies (perennial wadeable rivers and streams).
- Test the methods recommended by this plan for priority two water bodies.
- Refine the methods and recommendations for developing nutrient criteria for priority two water bodies based upon data analysis and lessons learned.

- Apply the refined method to compute draft criteria for priority two water bodies.

Year 5

- Complete data collection for priority three water bodies (perennial wadeable rivers and streams).
- Initiate data collection for priority four water bodies (perennial non-wadeable (large) rivers and stream) within all ecoregion / major drainage basin strata.
- Test the methods recommended by this plan for priority three water bodies.
- Refine the methods and recommendations for developing criteria based upon lessons learned for priority three water bodies.
- Apply the revised method to compute draft criteria for priority three water bodies.

Year 6

- Complete data collection for priority four water bodies (perennial non-wadeable (large) rivers and streams).
- Initiate data collection for priority five water bodies (intermittent/ephemeral streams).
- Test the methods recommended by this plan for priority four water bodies.
- Refine the methods and recommendations for developing criteria based upon lessons learned for priority four water bodies.
- Apply the revised method to compute draft criteria for priority four water bodies.
- Develop conceptual models for wetlands water body types.
- Complete review and analysis of existing surface water quality monitoring data for wetland systems at the recommended spatial and temporal scales.
- Modify current monitoring program design for wetland systems to fill data gaps and needs for criteria development.
- Complete an evaluation of known wetland reference sites.
- Complete additional Geographic Information System analysis to identify potential range of reference sites and other locations for wetland systems across the nutrient concentration gradient.
- Evaluate priorities recommended in this plan for criteria development and methods to reduce fiscal impact (e.g., implement by geographic region).
- Develop detailed budget for developing the nutrient criteria for wetland systems.

Year 7

- Complete data collection for priority five water bodies (intermittent/ephemeral streams).
- Initiate data collection for priority six water bodies (wetlands).
- Test the methods recommended by this plan for priority five water bodies.
- Refine the methods and recommendations for developing criteria based upon lessons learned for priority four water bodies.
- Apply the revised method to compute draft criteria for priority four water bodies.

Year 8

- Complete the data collection for priority six water bodies (wetlands).
- Test the methods recommended by this plan for priority six water bodies.
- Refine the methods and recommendations for developing criteria based upon lessons learned for priority five water bodies.
- Apply the revised method to compute draft criteria for priority five water bodies.

Year 9

- Implement criteria within North Dakota Century Code

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APPENDIX A
LEVEL III ECOREGIONS OF NORTH DAKOTA

The concept of defining or grouping broad landscapes based on environmental factors has been studied in North America for almost 45 years. However, the first national compilations of ecological classifications were proposed in the mid-1980's (CEC 1997). Ecoregions are broad geographic areas of similar land form, soil type, climate, flora and faunal communities. As such, rivers and lakes within ecoregions tend to show comparable traits.

There are four levels of detail in the ecoregion classification scheme, ranging from the continental scale (Level I) to a near-local scale (Level 4). Level III ecoregions characterize landscapes at a regional scale and are most appropriate for this plan. There are four Level III ecoregions within North Dakota (**Map 1**). The following descriptions are taken from the publication *Ecological Regions of North America* by the Commission for Environmental Cooperation (1997).

Northwestern Glaciated Plains, Ecoregion 42

This glaciated plains region comprises a transition between the generally more level, moister, more agricultural regions to the east and the generally more irregular, dryer regions to the southwest. The southern boundary roughly coincides with the limits of continental glaciation. Pocking this ecological region is a moderately high concentration of semi-permanent and seasonal wetlands, locally referred to as Prairie Potholes.

Northwestern Great Plains, Ecoregion 43

This ecological region encompasses the Missouri Plateau section of the Great Plains. It is a semiarid rolling plain of shale and sandstone punctuated by occasional buttes. Native grasslands, largely replaced on level ground by spring wheat and alfalfa, persist in rangeland areas on broken topography. Agriculture is constricted by erratic precipitation and limited opportunities for irrigation.

Northern Glaciated Plains, Ecoregion 46

This ecological region is characterized by a flat to gently rolling landscape composed of glacial till. The subhumid conditions foster transitional grassland containing tallgrass and shortgrass prairie. In its northern parts, mixed forests of aspen, lodgepole pine, and white spruce become prevalent. High concentrations of temporary and seasonal wetlands create favorable conditions for waterfowl nesting and migration. Though the till soils are very fertile, agricultural success is subject to annual climatic fluctuations.

Lake Agassiz Plain, Ecoregion 48

Glacial Lake Agassiz was the last in a series of proglacial lakes to fill the Red River valley in the three million years since the beginning of the Pleistocene. Thick beds of lake sediments on top of glacial till create the extremely flat floor of this region known as the Lake Agassiz Plain. The historic tallgrass prairie has been replaced by intensive row crop agriculture. The preferred crops in the northern half of the region are potatoes, beans, and wheat; soybeans and corn predominate in the south.

APPENDIX B
MAJOR DRAINAGE BASIN DESCRIPTIONS

There are five major hydrologic basins recognized by the State of North Dakota (**Map 2)**, where the Lower and Upper Red River Subbasins have been grouped into one major unit. Descriptions of these basins were excerpted from *Synopsis of Ground-water and Surface-water Resources of North Dakota* by Winter et al. (1984). In this report, the Lake Sakakawea and Lake Oahe Subbasins of the Missouri River have been grouped into one description for the Missouri River Mainstem Basin.

Red River (including Devils Lake) (includes Upper and Lower Red River Subbasins)

The Red River basin is a part of the Hudson Bay drainage system. Of the total drainage area, 20,820 square miles are located in North Dakota. This includes 3,800 square miles of the closed Devils Lake basin. The Ottertail and Bois de Sioux Rivers combine at Wahpeton, ND and Breckenridge, MN to form the Red River. The river flows northward for 394 miles to the United States-Canadian boundary. The Red River follows a meandering course through the broad, very flat bed of glacial Lake Agassiz. About one-half of the basins consist of the extremely flat lake plain, while the other half consists of an upland area with greater local relief. The principal tributaries are the Wild Rice, Sheyenne, Goose, and Pembina Rivers.

Souris River

The Souris River originates in southeastern Saskatchewan, Canada, flows southeasterly to enter North Dakota west of Sherwood, forms a loop in North Dakota, re-enters Canada near Westhope, and then flows to the Red River via the Assiniboine River in Canada. The topography in North Dakota varies from hilly moraines in the southwest part of the basin to gently rolling moraines and a flat glacial lake plain in the northeast part of the basin. The total drainage area in North Dakota is 9,130 square miles. Large areas within the overall basin have a poorly defined drainage pattern and are noncontributing to the streamflow. Major tributaries are the Des Lacs, Wintering, and Deep Rivers, and Willow and Boundary Creeks.

Missouri River Mainstem (includes Upper Missouri River (Lake Sakakawea) and Lower Missouri River (Lake Oahe) Subbasins)

The Missouri River mainstem drainage area within North Dakota consists of about 48 percent of the State. About 32,800 square miles of drainage area contribute to the Missouri River mainstem in North Dakota. The major tributaries are the Yellowstone, Little Missouri, Knife, Heart, and Cannonball Rivers, which drain the area to the west and south of the Missouri River. Most of the rivers in this western region flow through badland areas, which produce rapid and excessive runoff. Smaller tributaries, generally occupying large valleys of glacial origin, drain the area to the east and north. Tributaries in the eastern area originate in the lake wetlands area of the Coteau du Missouri where drainage is poorly integrated. Of the original 390 miles of river in the State, only the 90-mile reach between Garrison Dam and the upstream end of Lake Oahe near Bismarck, has not been inundated.

James River

The James River originates in Wells County in central North Dakota and follows a meandering course east and south for 260 miles to the state border. Near it headwaters, the channel is poorly defined, consisting of a series of small ponds or sloughs. The drainage area within North Dakota is 5,480 square miles, of which about 3,300 square miles is considered noncontributing. Relief through the basin is extremely slight, consisting of low hills, scattered lakes, and low bluffs along the river.

Table 1 – Lakes and Reservoirs Assessed in North Dakota.

System	Total Area (acres)
Artificial Reservoirs (134 total) including Lake Sakakawea and Lake Oahe	542,868
Lake Sakakawea and Lake Oahe	480,731
All other reservoirs excluding Lake Sakakawea and Lake Oahe	62,137
Natural Lakes (90 total) including Devils Lake	172,051
Devils Lake	125,000
All Other Natural Lakes, excluding Devils Lake	47,051
Grand Total	714,919

Table 2 – Streams and Rivers by Major Hydrologic Basin.

Basin	Total Length (miles)
Red River (including Devils Lake)	11,881
Souris River	3,645
Upper Missouri (Lake Sakakawea)	13,877
Lower Missouri (Lake Oahe)	22,271
James River	2,753
Grand Total	54,427

Table 3 – Primary Causes of Designated Beneficial Use Impairments.

Beneficial Use	Stressor or Cause	
	Lakes and Reservoirs	Rivers and Streams
Aquatic Life	Low Dissolved Oxygen	Nonpoint Source Pollution (siltation/sedimentation or stream habitat loss/degradation)
Recreational Use	Nutrients	Pathogens
Drinking Water	(no impairments)*	(no impairments)
Fish Consumption**	Methyl-mercury	Methyl-mercury

*Only 6 reservoirs established for drinking water; 3 fully support their designated use and the remaining three are not assessed.

**To date there have been no specific causes or sources identified for the mercury present in North Dakota fish.

Table 4 – Impaired Water Bodies by Type and Beneficial Use Identified in 2006.

Beneficial Use	Lakes and Reservoirs (acres)*	Rivers and Streams (miles)
Aquatic Life	171.8	1,941.48
Recreational Use	5,565.0	1,189.30
Drinking Water	0	0
Fish Consumption	493,231	399.23

*Represents a total of 47 lakes and reservoirs which were considered impaired.

Table 5 – NDDH Lake and Reservoir Sample Counts of Parameter by Level III Ecoregion (1993 - 2005).

Parameter	**Level III Ecoregion**				**Grand Total**
	42 Northwest Glaciated Plains	**43** Northwest Great Plains	**46** Northern Glaciated Plains	**48** Lake Agassiz Plains	
Ammonia (N)	727	1,793	2,764	258	5,542
Ammonia (N), Dissolved	0	70	4	0	74
Nitrate	613	1,241	2,441	228	4,523
Nitrogen, Total Kjeldahl	723	1,796	2,742	258	5,519
Nitrogen, Total	598	1,059	1,785	215	3,657
Nitrogen, Organic	0	0	0	0	0
Chlorophyll -a	268	562	1,208	79	2,117
Chlorophyll -b	241	445	1,049	76	1,811
Specific Conductivity	573	1,633	2,024	249	4,479
Dissolved Oxygen	29	65	9	0	103
Water Temperature	29	65	9	0	103
pH	575	1,633	1,955	249	4,412
Phosphorus, Dissolved as P	584	1,436	1,906	239	4,165
Phosphorus, Organic	0	0	0	0	0
Phosphorus, Total	727	1,793	2,748	260	5,528
Suspended Sediment	0	0	0	0	0
Suspended Solids, Total	87	58	77	16	238
Turbidity	0	0	0	0	0

Table 6 – NDDH River Sample Counts of Parameter by Level III Ecoregion (1993 - 2005).

Parameter	**Level III Ecoregion**				**Grand Total**
	42 Northwest Glaciated Plains	**43** Northwest Great Plains	**46** Northern Glaciated Plains	**48** Lake Agassiz Plains	
Ammonia (N)	No Data	5,714	2,877	12,097	20,688
Ammonia (N), Dissolved	No Data	116	2	58	176
Nitrate	No Data	5,080	2,469	11,606	19,155
Nitrogen, Total Kjeldahl	No Data	5,498	2,618	11,965	20,081
Nitrogen, Total	No Data	4,281	2,084	10,304	16,669
Nitrogen, Organic	No Data	No Data	No Data	No Data	No Data
Chlorophyll -a	No Data	3	212	38	253
Chlorophyll -b	No Data	3	217	38	258
Specific Conductivity	No Data	1,106	1,311	1,737	4,154
Dissolved Oxygen	No Data	84	124	61	269
Water Temperature	No Data	84	124	61	269
pH	No Data	1,056	1,192	1,451	3,699
Dissolved Phosphorus as P	No Data	502	300	355	1,157
Phosphorus, Organic	No Data	No Data	No Data	No Data	No Data
Phosphorus, Total	No Data	5,716	2,438	12,135	20,289
Suspended Sediment	No Data	No Data	No Data	No Data	No Data
Suspended Solids, Total	No Data	5,502	0	2,963	8,465
Turbidity	No Data	No Data	No Data	No Data	No Data

Table 7 – USGS Lake and Reservoir Sample Counts by Parameter and Ecoregion (1995 - 2005).

Parameter	**Level III Ecoregion**				**Grand Total**
	42 Northwest Glaciated Plains	**43** Northwest Great Plains	**46** Northern Glaciated Plains	**48** Lake Agassiz Plains	
Ammonia (N)	42	353	186	No Data	581
Ammonia (N), Dissolved	241	68	626	No Data	935
Nitrate (N) - Dissolved	1	4	17	No Data	22
Nitrogen, Total Kjeldahl	297	355	811	No Data	1,463
Nitrogen, Total	No Data	No Data	No Data	No Data	No Data
Nitrogen, Organic	7	No Data	68	No Data	75
Chlorophyll -a	No Data	No Data	No Data	No Data	No Data
Chlorophyll -b	109	105	534	No Data	748
Specific Conductivity[1]	1,525	3,797	3,789	No Data	9,111
Dissolved Oxygen	No Data	No Data	No Data	No Data	No Data
Water Temperature	1,515	3,789	3,742	No Data	9,046
pH	No Data	No Data	No Data	No Data	No Data
Phosphorus, Dissolved as P	14	288	187	No Data	489
Phosphorus, Organic	No Data	No Data	No Data	No Data	No Data
Phosphorus, Total	288	355	812	No Data	1,455
Suspended Sediment	No Data	No Data	16	No Data	16
Suspended Solids, Total	No Data	No Data	258	No Data	258
Turbidity[3]	1,048	127	36	No Data	1,211

Table 8 – USGS River and Stream Sample Counts by Parameter and Ecoregion (1995 – 2005).

Parameter	**Level III Ecoregion**				**Grand Total**
	42 Northwest Glaciated Plains	**43** Northwest Great Plains	**46** Northern Glaciated Plains	**48** Lake Agassiz Plains	
Ammonia (N)	No Data	105	156	274	535
Ammonia (N), Dissolved	127	143	648	235	1,153
Nitrate (N) - Dissolved	1	4	3	0	8
Nitrogen, Total Kjeldahl	No Data	171	681	412	1,264
Nitrogen, Total	No Data	No Data	No Data	No Data	No Data
Nitrogen, Organic	No Data	5	43	62	110
Chlorophyll -a	No Data	No Data	No Data	No Data	No Data
Chlorophyll -b	No Data	0	249	79	328
Specific Conductivity	470	2,064	3,144	2,244	7,922
Dissolved Oxygen	No Data	No Data	No Data	No Data	No Data
Water Temperature	432	1,977	2,967	2,127	7,503
pH	No Data	No Data	No Data	No Data	No Data
Phosphorus, Dissolved as P	0	107	355	339	801
Phosphorus, Organic	No Data	No Data	No Data	No Data	No Data
Phosphorus, Total	No Data	174	684	414	1,272
Suspended Sediment	4	114	318	361	797
Suspended Solids, Total	No Data	No Data	486	64	550
Turbidity[3]	108	62	17	176	363

Table 9 – EMAP Western Pilot Project Sample Counts by Parameter and Ecoregion in North Dakota.

Parameter	**Level III Ecoregion**				**Grand Total**
	42 Northwest Glaciated Plains	**43** Northwest Great Plains	**46** Northern Glaciated Plains	**48** Lake Agassiz Plains	
Ammonia (N)	No Data	No Data	No Data	No Data	No Data
Ammonia (N), Dissolved	No Data	No Data	No Data	No Data	No Data
Nitrate (N)	No Data	40	38	33	111
Nitrogen, Total Kjeldahl	No Data	No Data	No Data	No Data	No Data
Nitrogen, Total	No Data	40	38	33	111
Nitrogen, Organic	No Data	No Data	No Data	No Data	No Data
Chlorophyll -a	No Data	No Data	No Data	No Data	No Data
Chlorophyll -b	No Data	No Data	No Data	No Data	No Data
Specific Conductivity	No Data	40	38	33	111
Dissolved Oxygen	No Data	No Data	No Data	No Data	No Data
Water Temperature	No Data	No Data	No Data	No Data	No Data
pH	No Data	No Data	No Data	No Data	No Data
Phosphorus, Dissolved as P	No Data	No Data	No Data	No Data	No Data
Phosphorus, Organic	No Data	No Data	No Data	No Data	No Data
Phosphorus, Total	No Data	40	38	33	111
Suspended Sediment	No Data	No Data	No Data	No Data	No Data
Suspended Solids, Total	No Data	40	38	33	111
Turbidity	2	40	38	33	113

Table 10 - EMAP Western Pilot Project Impacted Sample Sites in North Dakota.

Year	**Level III Ecoregion**				**Grand Total**
	42 Northwest Glaciated Plains	**43** Northwest Great Plains	**46** Northern Glaciated Plains	**48** Lake Agassiz Plains	
2000	No Data	7	9	7	23
2001	No Data	9	13	8	30
2002	1	4	7	4	16
2003	No Data	6	4	3	13
2004	No Data	4	No Data	No Data	4
Grand Total	1	30	33	22	86

Table 11 - EMAP Western Pilot Project Reference Sample Sites in North Dakota.

Year	Level III Ecoregion				Grand Total
	42 Northwest Glaciated Plains	**43** Northwest Great Plains	**46** Northern Glaciated Plains	**48** Lake Agassiz Plains	
2000	No Data	No Data	No Data	No Data	No Data
2001	No Data	No Data	No Data	No Data	No Data
2002	No Data	No Data	1	11	12
2003	1	8	No Data	No Data	9
2004	No Data	No Data	No Data	No Data	No Data
Grand Total	1	8	1	11	21

Notes:
No information was available for the Sheyenne River Pilot reference sites used by Zheng et. al., 2005).
Data for Ecoregion 42 is on the edge of the boundary between 42 and 43.
Targeted riffle data not included in these summaries.

Table 12

Potential Nutrient Criteria Based Upon the Statistical Approach Recommended by EPA.

Lakes and Reservoirs

	Aggregate Ecoregion IV Level III Ecoregion 43 (Southwest N.D.)		Aggregate Ecoregion V Level III Ecoregion 42 (Central N.D.)		Aggregate Ecoregion VI Level III Ecoregions 46 and 48 (Eastern N.D.)	
Parameter	EPA	Richards	EPA	Richards	EPA	Richards*
Total Phosphorus (mg/L)	0.020	0.020	0.033	0.030	0.038	0.115
Total Nitrogen (mg/L)	0.44	-	0.56	1.10	0.78	1.20
Chlorophyll-a (ug/L)	2.00	3.00	2.30	3.00	8.59	4.00
Secchi Depth (m)	2.00	-	1.30	-	1.36	-

Rivers and Streams

	Aggregate Ecoregion IV Level III Ecoregion 43 (Southwest N.D.)		Aggregate Ecoregion V Level III Ecoregion 42 (Central N.D.)		Aggregate Ecoregion VI Level III Ecoregions 46 and 48 (Eastern N.D.)	
Parameter	EPA	Richards	EPA	Richards	EPA	Richards*
Total Phosphorus (mg/L)	0.023	0.040	0.067	0.070	0.076	0.150
Total Nitrogen (mg/L)	0.56	0.39	0.88	0.85	2.18	0.94
Chlorophyll-a (ug/L)	2.40	-	3.00	-	2.70	-
Secchi Depth (m)	4.21	-	7.83	-	6.36	-

Data presented represents 25th percentile of sample set values for lakes and streams
*Richards data shown for aggregate Ecoregion VI is an average of Level III ecoregions 46 and 48

Table 13

Summary of Literature Compiled and Reviewed for the Development of Nutrient Criteria within North Dakota.

Title	Year	Publisher	Primary Contact	Reference Number	Publication Type
Arkansas Nutrient Criteria Development Plan	2006	Arkansas Department of Environmental Quality	not listed	not listed	Fact sheet
Data Availability and Proposed Analysis Scheme for Nutrient Assessment using South Dakota's Ambient Monitoring Program Data	2004	Unpublished	R. Peter Richards	not listed	Report
Developing Nutrient Criteria for Louisiana	2006	Louisiana Department of Environmental Quality	not listed	not listed	Report
Development and Adoption of Nutrient Criteria into Water Quality Standards	2001	US EPA	Geoffrey Grubbs	WQSP-01-01	Memoradum
EMAP - West Communications. How Reference Condition is Used in Surface Water Monitoring	2002	US EPA	John Stoddard	EPA A620/R-01/004d	Fact sheet
EPA's EMAP Probability Monitoring Approach: More Than Just 305(b)?	not dated	US EPA	not listed	not listed	PowerPoint Handout
Establishing Nutrient Criteria in Streams	2000	Journal of North American Benthological Society	Walter Dodds	not listed	Journal Article
Establishing Reference Conditions for Assessing the Biological Integrity of Western Streams	not dated	Utah State University	Charles Hawkins	not listed	PowerPoint Handout
Guidance Manual for Assessing the Quality of Minnesota Surface Waters for the Determination of Impairment	2004	Minnesota Pollution Control Agency	not listed	not listed	Report
Minnesota Lake Water Quality Assessment Report: Developing Nutrient Criteria (3rd Ed.)	2005	Minnesota Pollution Control Agency	Steve Heiskary	not listed	Report
National Strategy for the Development of Regional Nutrient Criteria	1998	US EPA	Amy Parker	Unlisted	Fact sheet
National Strategy for the Development of Regional Nutrient Criteria	1998	US EPA	not listed	EPA 822-R-98-002	Report
North Carolina Nutrient Criteria Implementation Plan	2004	State of North Carolina	not listed	not listed	Report
Nutrient Criteria Adoption Plan	2002	Maine Department of Environmental Protection	not listed	not listed	Report
Nutrient Criteria Development in Washington State	2004	Washington State Department of Ecology	Allen Moore	04-10-033	Report
Nutrient Criteria Development Plan for Colorado	2002	Colorado Department of Public Health and Environment	not listed	not listed	Report
Nutrient Criteria Development Plan for the Commonwealth of Virginia	2004	Virginia Department of Environmental Quality	not listed	not listed	Report
Nutrient Criteria for Florida Lakes: A Comparison of Approaches	2002	Florida Department of Environmental Protection	Michael Paul (Tetra Tech)	not listed	Report
Nutrient Criteria for Montana's Flowing Waters: What We've Done, Where We're Going	2006	Montana Department of Environmental Quality	Michael Suplee	not listed	PowerPoint Handout
Nutrient Criteria Technical Guidance Manual - Lakes and Reservoirs	2000	US EPA	Various	EPA-822-B-00-001	Report
Nutrient Criteria Technical Guidance Manual - Rivers and Streams	2000	US EPA	Various	EPA-822-B-00-002	Report
Nutrient Stations Georeferenced to NHD: Value to Nutrient Criteria Development	not dated	US EPA	Ifeyinwa Davis	not listed	Report
Nutrient Status of Lakes and Reservoirs in North Dakota	2000	Unpublished	R. Peter Richards	not listed	Report
Nutrient Status of Rivers and Streams in North Dakota	2000	Unpublished	R. Peter Richards	not listed	Report
Peer Review Comments and Responses on National Nutrient Strategy	not dated	US EPA	not listed	not listed	Working Document
Standards work plan: Development of numeric algal biomass and nutrient standards for Montana's waters	2002	Montana Department of Environmental Quality	Michael Suplee	not listed	Report
Technical Approach to Develop Nutrient Numeric Endpoints for California	2005	California State Water Resource Control Board	Clayton Creager (Tetra Tech)	68-C-02-108-To-111	Draft Report
Vermont Nutrient Criteria Development Project -- Final Data Report	2006	Vermont Department of Environmental Conservation	Neil Kamman	not listed	Report
Vermont Plan for the Development of Nutrient Criteria for Lakes and Rivers	2002	Vermont Department of Environmental Conservation	not listed	not listed	Report
Wadeable Streams of Montana's Hi-line Region: An Analysis of Their Nature and Condition, with an Emphasis on Factors Affecting Aquatic Plant Communities and Recommendations to Prevent Nuisance Algae Conditions	2004	Montana Department of Environmental Quality	Michael Suplee	not listed	Report
Wadeable Streams of North Dakota's Northern Glaciated Plains: Nutrient Criteria Development	2005	North Dakota Department of Health	Lei Zheng (Tetra Tech)	68-C-01-041	Report
Work Plan to Develop Nutrient Standards for Utah's Waters	2005	Utah Department of Environmental Quality	Theron Miller	not listed	Draft Report

Table 14

Summary of State Nutrient Criteria Development Plans for Lakes and Reservoirs

					Identified Standard										
State	Contact Person	Waterbody Classification Approach	Targeted Beneficial Use	Nutrient Criteria Approach	Primary Indicator(s)	Established Value	Temporal Scale	Secondary Indicator(s)	Established Value	Temporal Scale	Reference Condition Definition	Site-specific Mechanism?[2]	Implementation Priority	Data Gaps or Issues	Comments
Montana	Michael Suplee, Ph.D.	Ecoregion level III & Morphometry; See comment for Reservoirs	Aquatic life & fisheries; recreation& aesthetics	Effects-based	TP, TN	TBD	undefined	Chlorophyll-a, Secchi	TBD	undefined	undefined	Yes, translator mechanism planned	undefined	Need lake morphometry	Cassification of reservoirs will be detailed later: Ecoregion based but will look at different factors (such as residence time)
Utah	Theron Miller, Ph.D.	Beneficial use, with sub-classes based on ecoregion, morphology, and other characteristics	Aquatic life; drinking water	Combination of approaches	TP, NO3	TBD	undefined	Chlorophyll-a, Secchi, degree of dominance of nuisance algal species	TBD	undefined	Statistical	Weight of Evidence [3]		--	Reservoirs may have different sub-class stratification factors
Colorado	Colorado Dept. of Public Health and Environment	Site-specific empirical approach, with physical factors considered	Aquatic life	Effects-based (predictive models)	TP, TN	TBD	TBD, data collection will look at seasonal.	Chlorophyll-a, algal communities, transparency	TBD	TBD, data collection will look at seasonal.	TBD	Acknowledged possibility for site-specific assessments	Example Table; High, medium, low	Minimal data for Chlorophyll-a and algal communities	Additional cause and response variables may be considered. Interim measures for waterbody protection being explored.
Minnesota	Steve Heiskary	Ecoregion, morphometry	Aquatic life; recreational use	Effects-based, using relationships of causal and response variables	TP	Varies by ecoregion and beneficial use	Seasonal	Chlorophyll-a, secchi	Varies by ecoregion and beneficial use	Seasonal	Statistical (interquartile range)	No.		--	Different standards for shallow and deep lakes; multiple
California	California State Water Resource Control Board	3 Risk categories based on benefical uses: Presumed unimpaired, possibly impaired, presumed impaired	Aquatic life; recreational use, drinking water	Effects-based (risk analysis approach)	None	None		Chlorophyll-a, secchi, DO, pH	Varies by beneficial use	Varies by beneficial use and indicator	undefined	Acknowledged possibility for site-specific assessments	No.	--	Proposed numeric criteria defines boundaries between risk categories
Florida	Florida Dept. of Environmental Protection	5 classes based on color and pH	Undefined	Combination of reference and effects-based approaches, with TAC input	TP, TN	Provisional values; vary by technical method and waterbody class	undefined	Chlorophyll-a, Secchi	Provisional values; vary by technical method and waterbody class	undefined	TBD; three methods proposed	No.	No.	--	
North Dakota	Mike Ell	(pending finalization of report)	(pending finalization of report)	(pending finalization of report)	(pending finalization of report)	(pending finalization of report)	(pending finalization of report)	(pending finalization of report)	(pending finalization of report)	(pending finalization of report)	(pending finalization of report)	(pending finalization of report)	(pending finalization of report)	(pending finalization of report)	

Footnotes

1) Current system (e.g., 3A, 3B) is based on beneficial uses

2) Needed where insufficient data exist, site-specifc conditions are unique, or downstream impacts warrant additional nutrient control (e.g. TMDL)
(A translator mechansim would outline specific approaches to developing standards on waterbodies on a case-by-case basis.)

3) Weight of Evidence means examining multiple criteria to assess resources which are borderline between classes or criteria.

General Notes

TBD = To be determined. Author acknowledges the need to address this factor in developing criteria.

Undefined = Report does not clearly acknowledge or state the approach

Table 15

Summary of State Nutrient Criteria Development Plans for Streams and Rivers

					Identified Standard										
State	Contact Person	Waterbody Classification Approach	Targeted Beneficial Use	Nutrient Criteria Approach	Primary Indicator(s)	Established Value	Temporal Scale	Secondary Indicator(s)	Established Value	Temporal Scale	Reference Condition Definition	Site-specific Mechanism?[2]	Implementation Priority	Data Gaps or Issues	Comments
Montana	Michael Suplee, Ph.D.	Current system[1], plus Ecoregion level III & Stream class (Rosgen)	Aquatic life & fisheries; recreation& aesthetics	Effects-based	TP, TN	TBD	undefined	Chlorophyll-a, Turbidity	TBD	undefined	undefined	Yes, translator mechanism planned	undefined	Will need Rosgen stream class	*Current stream classification system based salinity and temperature
Utah	Theron Miller, Ph.D.	Current system[1], plus Ecoregion level III & Stream class (Rosgen)		Combination of approaches	undefined	Currently, impairment value: TP > 50 ppb	undefined	undefined	Currently, impairment value: D.O. thresholds	undefined	Probablistic sampling based on EMAP	Yes, translator mechanism planned	Reference site development		Relationships between nutrients, excess biomass, and DO.
Colorado	Colorado Dept. of Public Health and Environment	Site-specific empirical approach, with physical factors considered	Aquatic life	Reference based (expected conditions)	TP, TN	TBD	TBD, data collection will look at seasonal.	Chlorophyll-a, algal communities, transparency	TBD	TBD, data collection will look at seasonal.	TBD	Acknowledged possibility for site-specific assessments	undefined	Minimal data for Chlorophyll-a and algal communities	Additional cause and response variables may be considered
Minnesota	Steve Heiskary	Ecoregion	Aquatic life; recreational use	Effects-based [3]				IBI	Impairment thresholds		Statistical (interquartile range)			--	Data for streams and rivers solely considered guidance; based on state narrative standard
California	California State Water Resource Control Board	3 Risk categories based on benefical uses: Presumed unimpaired, possibly impaired, presumed impaired	Aquatic life; recreational use, drinking water	Effects-based (risk analysis approach)	None	None		Benthic algal diversity, D.O., pH	Varies by beneficial use	Varies by beneficial use and indicator	undefined	Acknowledged possibility for site-specific assessments	No.	--	Proposed numeric criteria defines boundaries between risk categories
Florida (not applicable for streams)															
North Dakota	Mike Ell	(pending finalization of report)	(pending finalization of report)	(pending finalization of report)	(pending finalization of report)	(pending finalization of report)	(pending finalization of report)	(pending finalization of report)	(pending finalization of report)	(pending finalization of report)	(pending finalization of report)	(pending finalization of report)	(pending finalization of report)	(pending finalization of report)	

Footnotes

1) Current system (e.g., 3A, 3B) is based on beneficial uses

2) Needed where insufficient data exist, site-specifc conditions are unique, or downstream impacts warrant additional nutrient control (e.g. TMDL)
(A translator mechansim would outline specific approaches to developing standards on waterbodies on a case-by-case basis.)

3) Minnesota does not have nutrient criteria specifically articulated. Information shown reflects approach for assessing impairment.

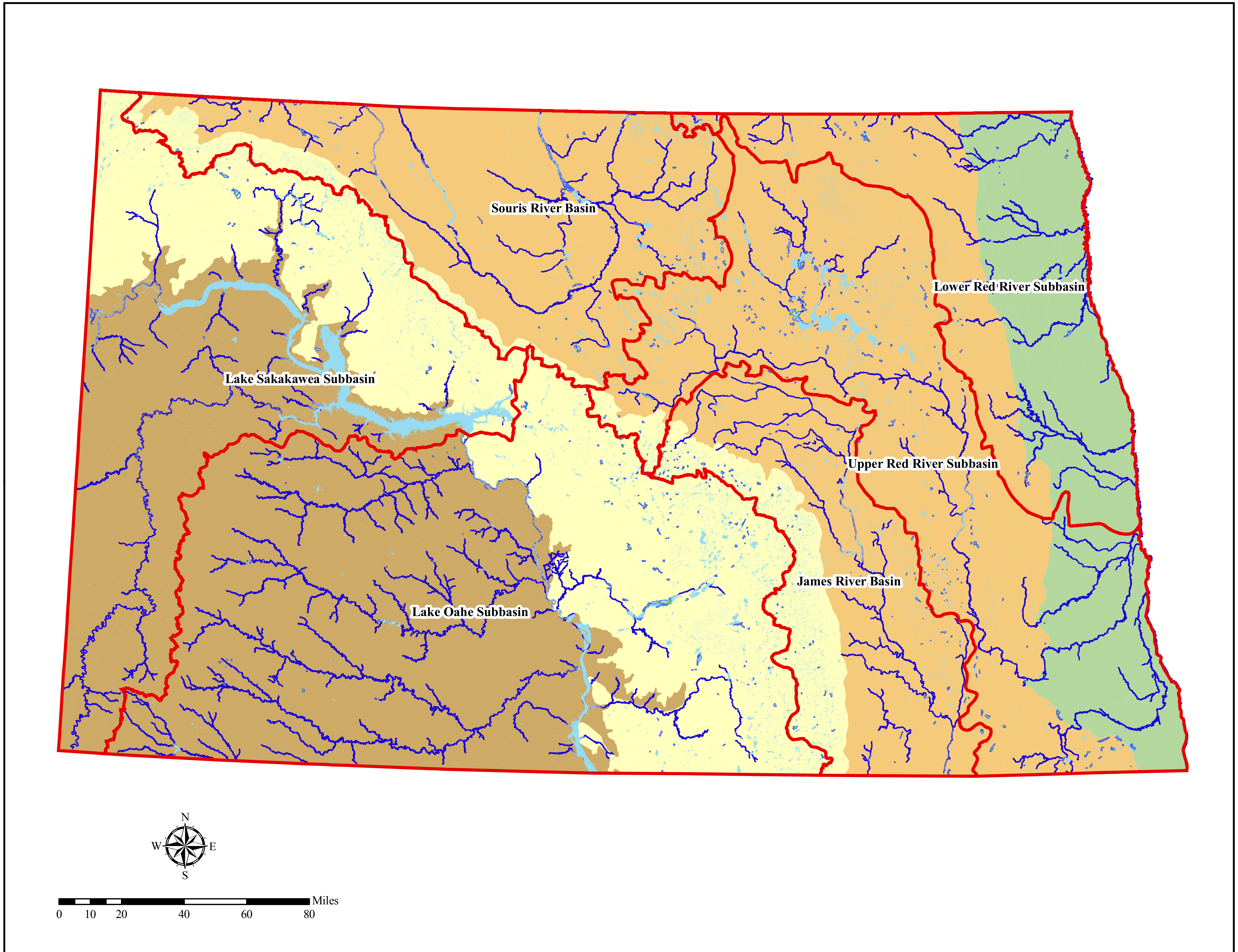
General Notes

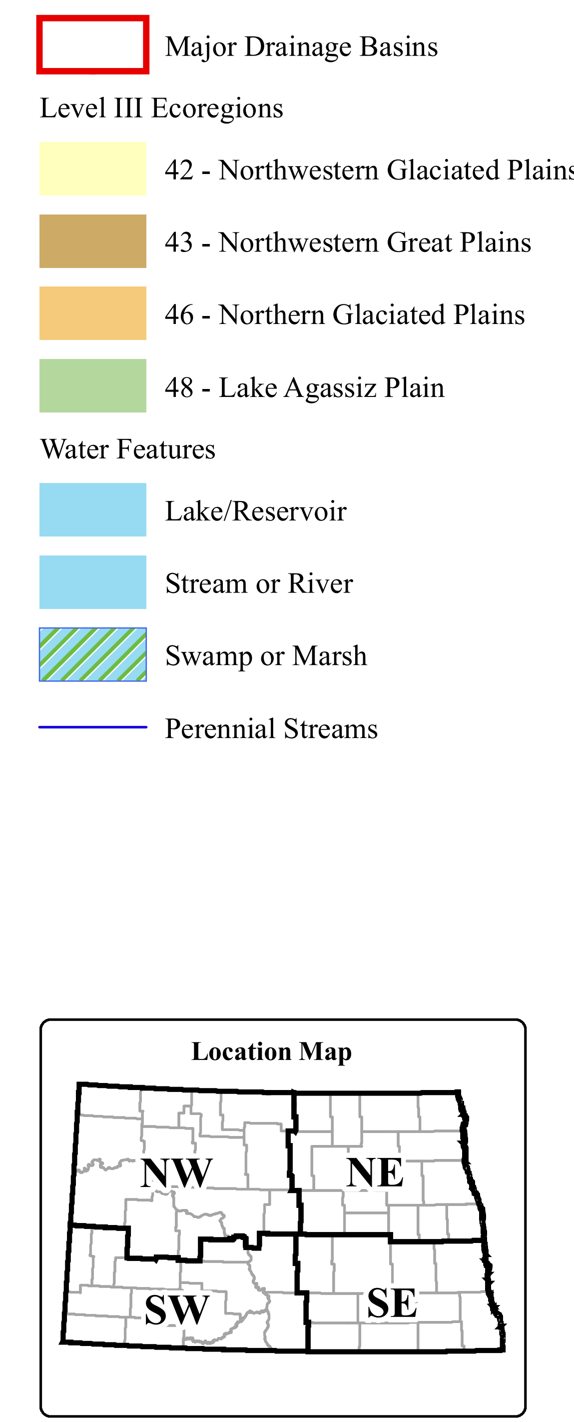
TBD = To be determined. Author acknowledges the need to address this factor in developing criteria.

Undefined = Report does not clearly acknowledge or state the approach

Table 16 - Paired Nutrient Concentrations (Causative) Data and Response Data By water Body Type and Monitoring Program

Waterbody Type / Monitoring Program	Paired Parameters	Ecoregion			
		42 Northwest Glaciated Plains	**43** Northwest Great Plains	**46** Northern Glaciated Plains	**48** Lake Agassiz Plains
Lakes and Reservoirs					
Western EMAP	turbidity, total-n, and total-p	No Data	No Data	No Data	No Data
USGS NWIS	turbidity and total-p	241	No Data	No Data	No Data
NDDH	chlorophyl-a, total-n, and total-p	205	348	709	204
Rivers & Streams					
Western EMAP	turbidity, total-n, and total-p	No Data	40	38	33
USGS NWIS	turbidity and total-p	No Data	57	13	92
NDDH	chlorophyl-a, total-n, and total-p	No Data	No Data	38	39





Data Source: ND Department of Health and ND GIS Hub.

Note: Lower and Upper Red River subbasins are considered together as one major basin.

Map 1: Level III ecoregions & major drainage basins

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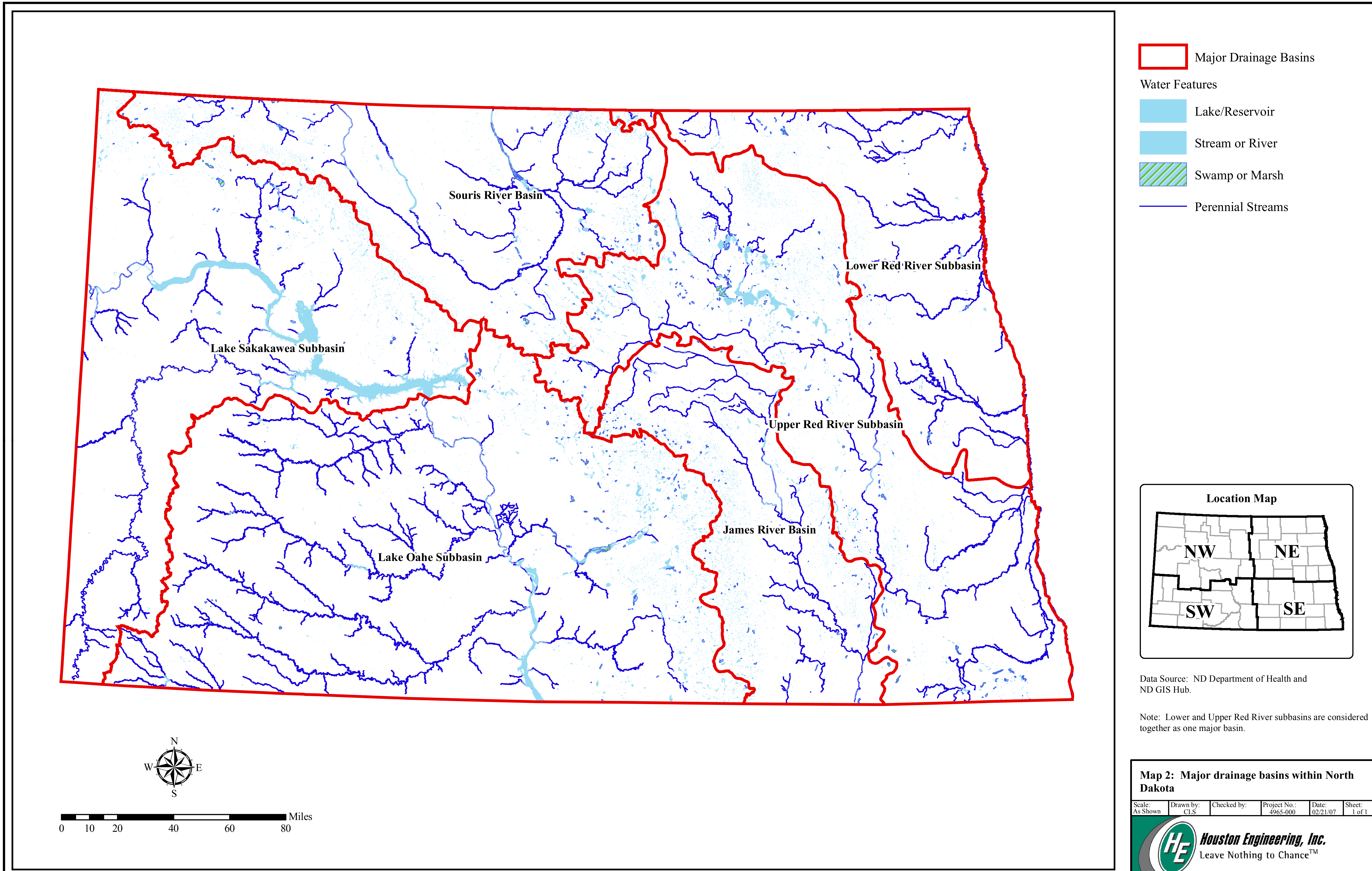
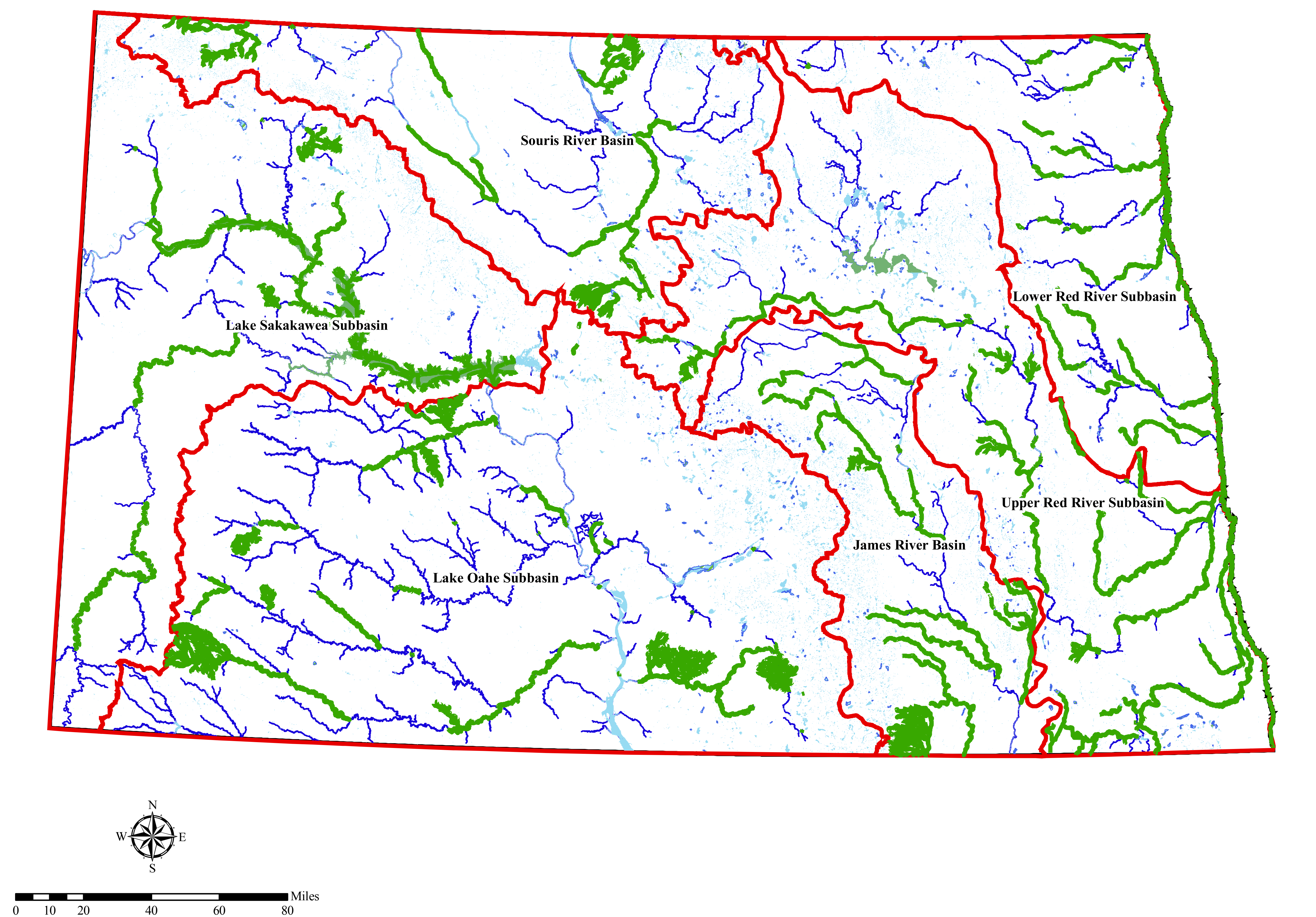


Map 2: Major drainage basins within North Dakota



Major Drainage Basins

2006 Impaired Waters

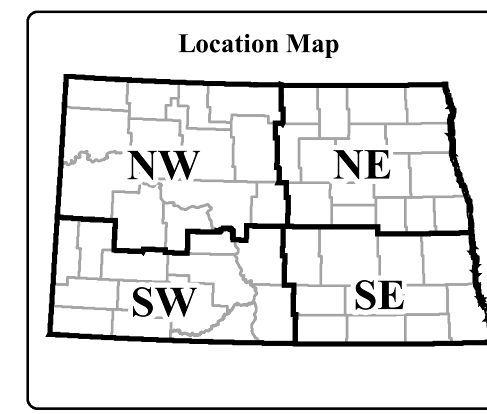
Water Features

Lake/Reservoir

Stream or River

Swamp or Marsh

Perennial Streams



Data Source: ND Department of Health and ND GIS Hub.

Note: The listing of impaired waters includes mercury in fish tissue which is not associated with nutrient criteria development.

Map 3: Impaired waters on the State of North Dakota 303(d) list

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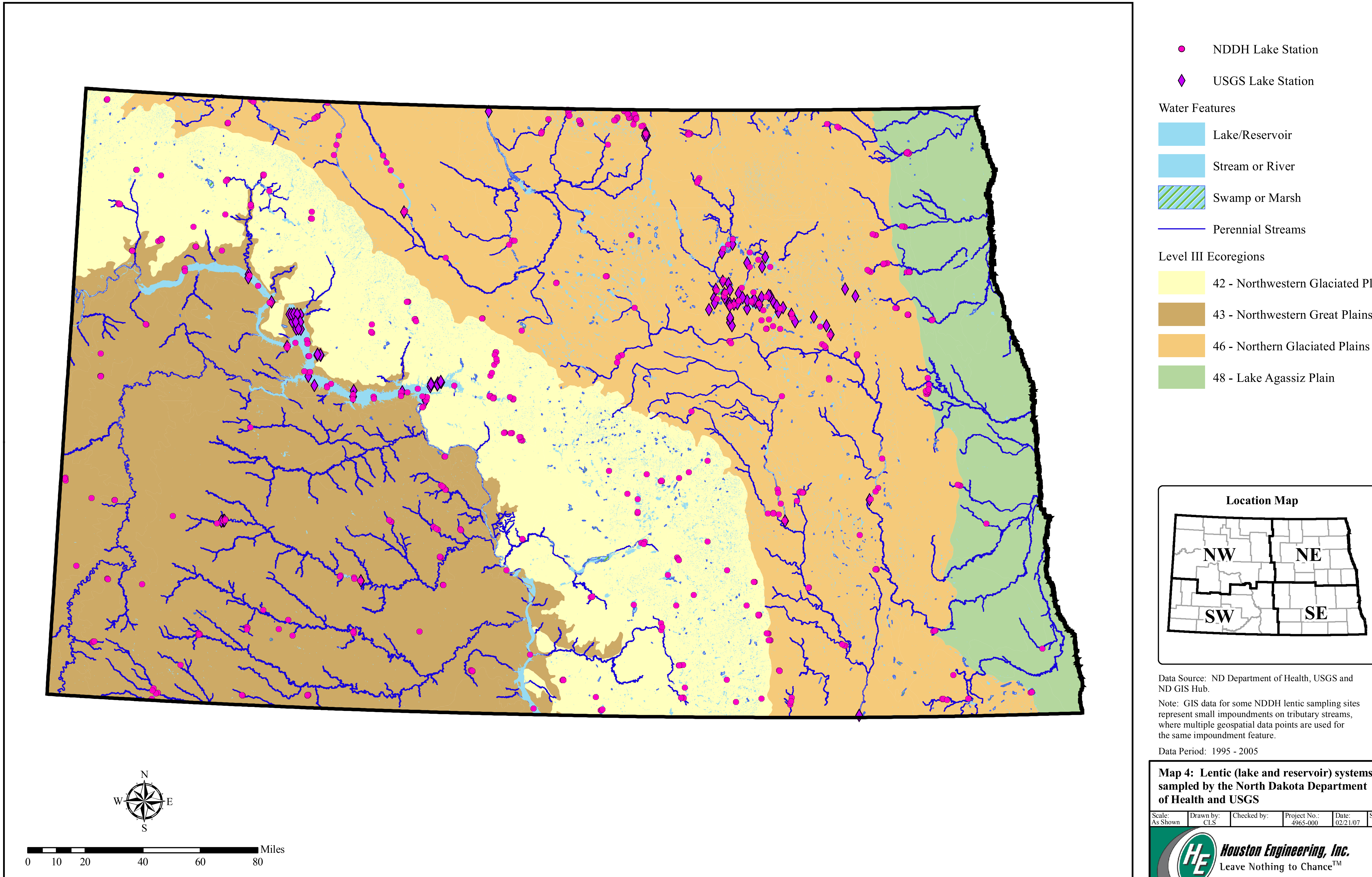

Data Source: ND Department of Health, USGS and ND GIS Hub.

Note: GIS data for some NDDH lentic sampling sites represent small impoundments on tributary streams, where multiple geospatial data points are used for the same impoundment feature.

Data Period: 1995 - 2005

Map 4: Lentic (lake and reservoir) systems sampled by the North Dakota Department of Health and USGS

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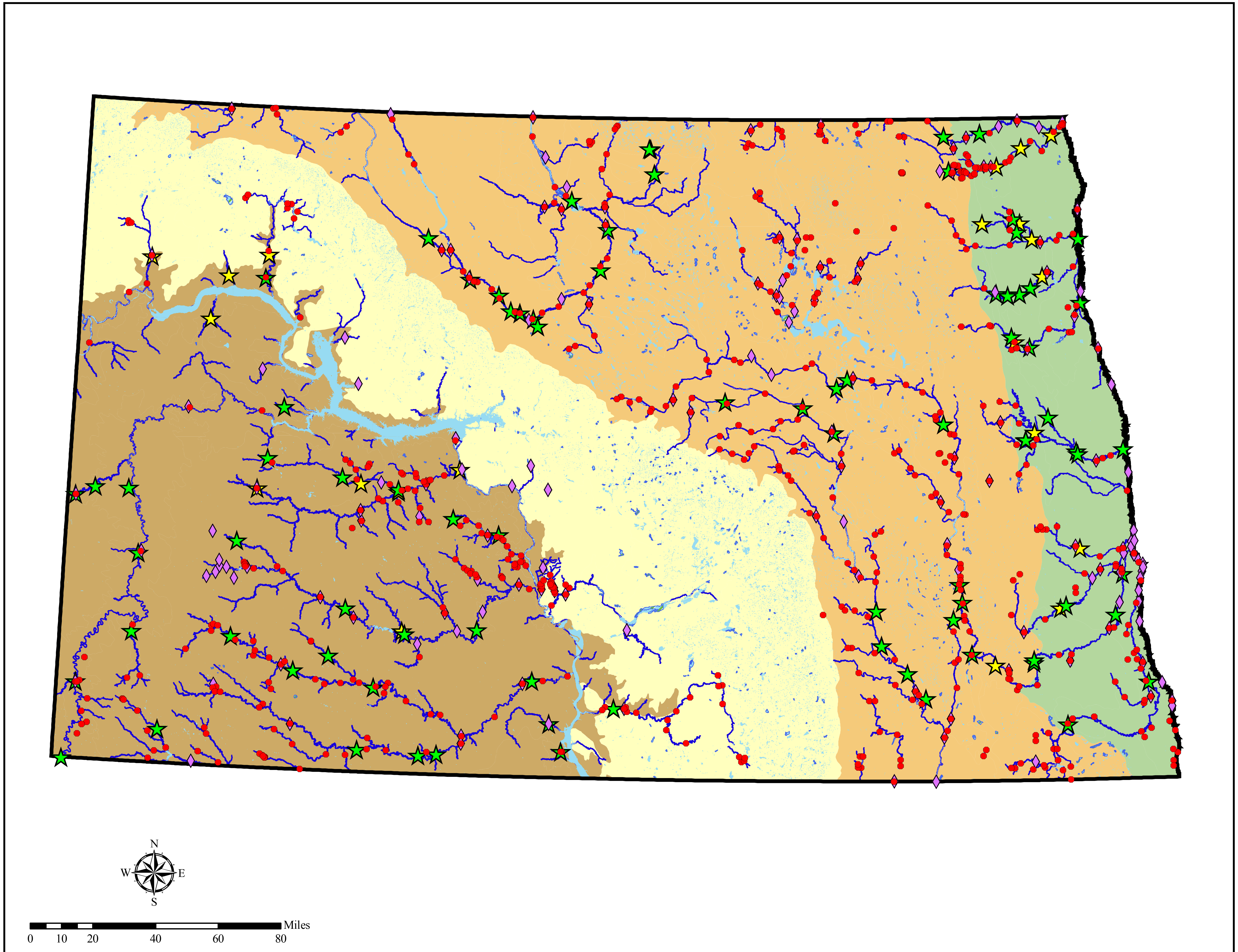


NDDH River Station

USGS River Station

EMAP Impacted Station

EMAP Reference Station

Water Features

Lake/Reservoir

Stream or River

Swamp or Marsh

Perennial Streams

Level III Ecoregions

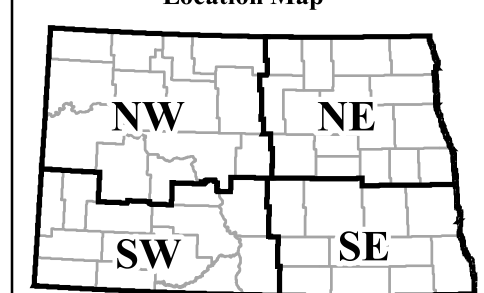
42 - Northwestern Glaciated Plains

43 - Northwestern Great Plains

46 - Northern Glaciated Plains

48 - Lake Agassiz Plain

Location Map



Data Source: ND Department of Health, USGS and ND GIS Hub.

Data Period: 1995 - 2005

Map 5: Lotic (stream and river) systems sampled by the North Dakota Department of Health, the USGS, and the EPA.

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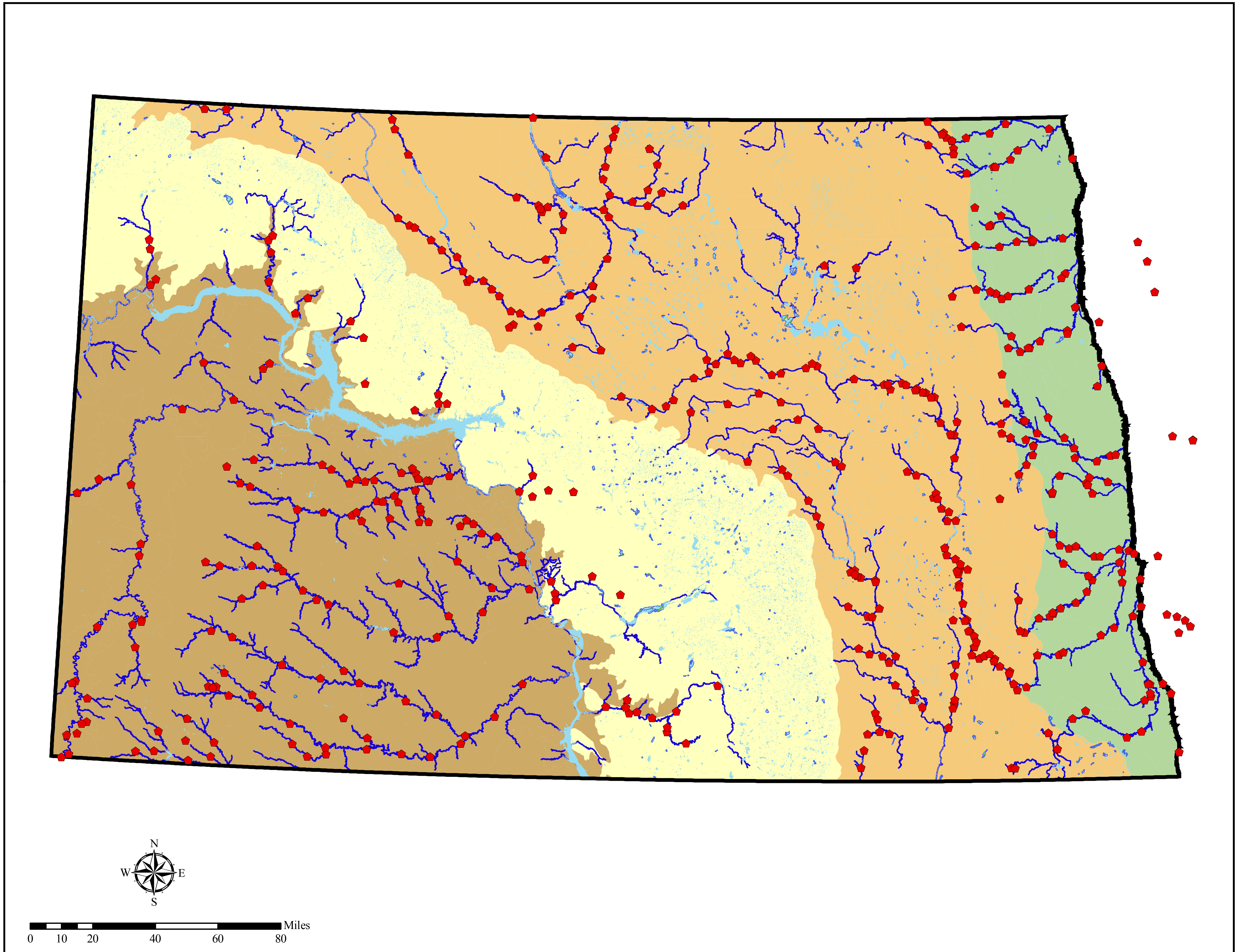

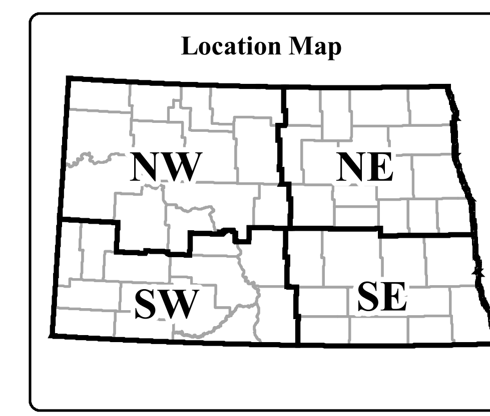

Data Source: ND Department of Health, USGS and ND GIS Hub.

Data Period: 1995 - 2005

Map 6: Macroinvertebrate and fish biological assessment monitoring locations used by the North Dakota Department of Health

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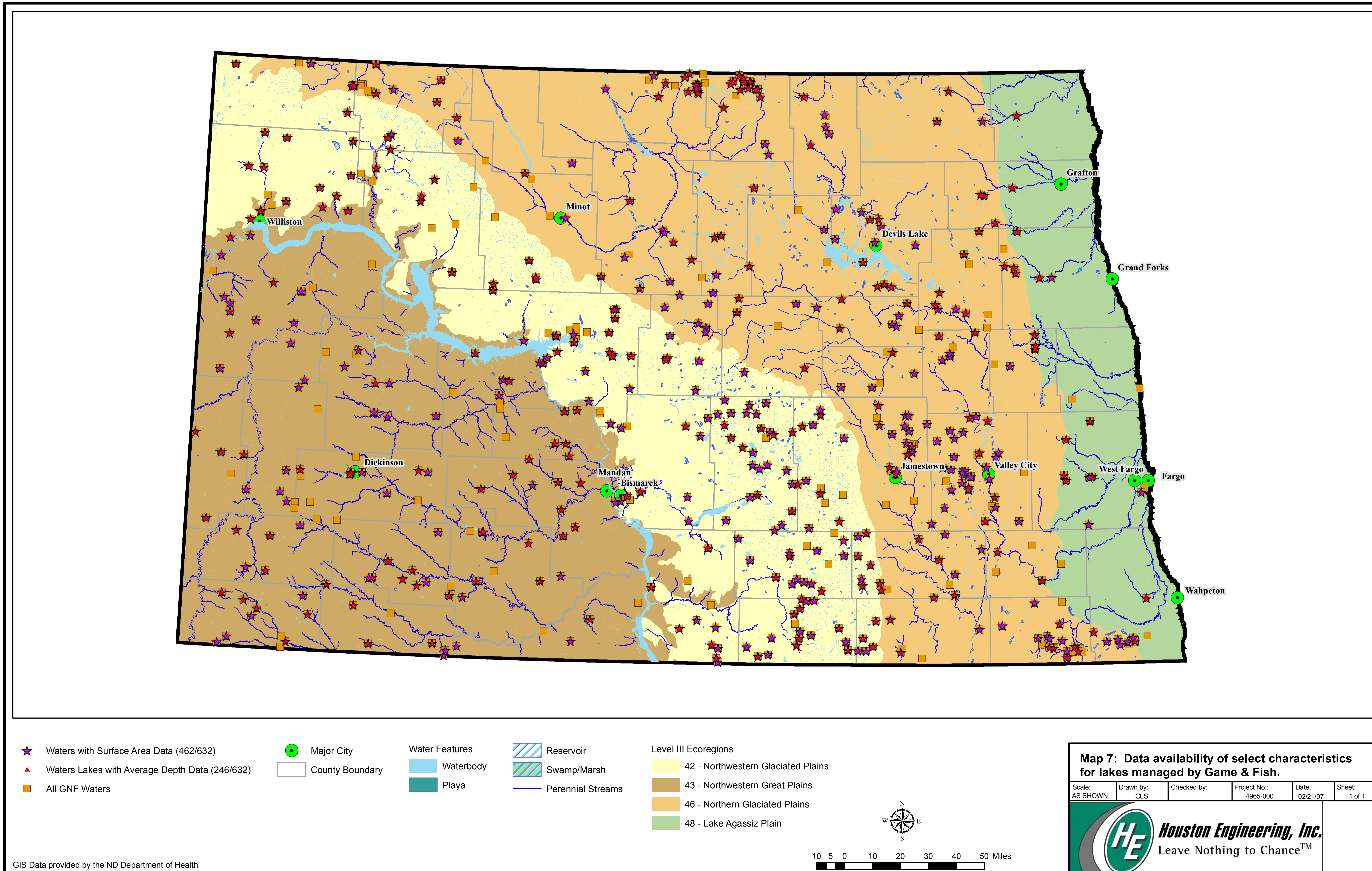
Grafton
Minot
Williston
Devils Lake
Grand Forks
Dickinson
Mandan
Bismarck
Jamestown
Valley City
West Fargo
Fargo
Wahpeton
Waters with Surface Area Data (462/632)
Waters Lakes with Average Depth Data (246/632)
All GNF Waters
Major City
County Boundary
Water Features
Waterbody
Playa
Reservoir
Swamp/Marsh
Perennial Streams
Level III Ecoregions
42 - Northwestern Glaciated Plains
43 - Northwestern Great Plains
46 - Northern Glaciated Plains
48 - Lake Agassiz Plain
N
W
E
S
10 5 0 10 20 30 40 50 Miles
GIS Data provided by the ND Department of Health
Map 7: Data availability of select characteristics for lakes managed by Game & Fish.
Scale: AS SHOWN
Drawn by: CLS
Checked by:
Project No.: 4965-000
Date: 02/21/07
Sheet: 1 of 1
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